THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE ASSISTANT-SECRETARY OF THE GEOLOGICAL SOCIETY.

> Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

VOLUME THE SIXTY-SEVENTH.

1911.

LONDON:
LONGMANS, GREEN, AND CO.
PARIS: CHARLES KLINCKSIECK, 11 RUE DE LILLE.
SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.
MDCCCCXI.

List

OF THE

OFFICERS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

Elected February 17th, 1911.

President.

Prof. William Whitehead Watts, Sc.D., LL.D., M.Sc., F.R.S.

Vice-Presidents.

Charles William Andrews, B.A., D.Sc., F.R.S.
Alfred Harker, M.A., F.R.S.
John Edward Marr, Sc.D., F.R.S.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.

Secretaries.

Prof. Edmund Johnston Garwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S.

Foreign Secretary.

Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.

Treasurer.

Aubrey Strahan, Sc.D., F.R.S.

COUNCIL.

Henry A. Allen.
Tempest Anderson, M.D., D.Sc.
Charles William Andrews, B.A., D.Sc., F.R.S.
Henry Howe Arnold-Bemrose, J.P., Sc.D.
George Barrow.
Prof. Thomas George Bonney, Sc.D., LL.D., F.R.S.
Prof. William S. Boulton, B.Sc.
James Vincent Elsden, D.Sc.
John Smith Flett, M.A., D.Sc.
Prof. Edmund Johnston Garwood, M.A.
Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.
Alfred Harker, M.A., F.R.S.
Robert Stansfield Herries, M.A.
Bedford McNeill, Assoc.R.S.M.
John Edward Marr, Sc.D., F.R.S.
George Thurland Prior, M.A., D.Sc.
Prof. Sidney Hugh Reynolds, M.A.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.
Aubrey Strahan, Sc.D., F.R.S.
Herbert Henry Thomas, M.A., B.Sc.
Prof. William Whitehead Watts, Sc.D., LL.D., M.Sc., F.R.S.
The Rev. Henry Hoyte Winwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

Assistant-Secretary, Clerk, Librarian, and Curator.

L. L. Belinfante, M.Sc.

Assistants in Office, Library, and Museum.

W. Rupert Jones. Clyde H. Black.
Arthur Greig.

STANDING PUBLICATION COMMITTEE.

Prof. W. W. Watts, *President*.

Prof. E. J. Garwood,
Dr. A. Smith Woodward, } *Secretaries.*

Mr. H. A. Allen.
Dr. C. W. Andrews.
Dr. J. V. Elsden.
Dr. J. S. Flett.
Mr. A. Harker.
Mr. R. S. Herries.
Dr. J. E. Marr.
Dr. G. T. Prior.
Prof. S. H. Reynolds.
Prof. W. J. Sollas.
Dr. A. Strahan.
Mr. H. H. Thomas.

TABLE OF CONTENTS.

PROCEEDINGS.

LIST OF THE FOSSILS FIGURED AND DESCRIBED IN THIS VOLUME.

Name of Species.	Formation.	Locality.	Page
	Foraminifera.		
Lepidocyclina elephantina	Aquitanian	Wadi Umzigga	660
Nummulites curvispira, var. *major* nov.	Middle Eocene	Cyrenaica	659
Orthophragmina pratti	Eocene	Derna, etc.	659–60
	Graptolitoidea.		
Cyrtograptus rigidus, figs. 2 & 3	Wenlock Beds	Wandale Hill, etc.	234–35
Diplograptus (Amplexograptus) perexcavatus, fig. 10	Trilobite-Dingle Shales	N.E. Montgomeryshire	456
Monograptus vulgaris, fig. 11	Ludlow Beds		456
—— *wandalensis* sp. nov., fig. 4		Wandale Hill	235–36
	Madreporaria rugosa.		
Amplexus (?) sp., pl. xl, figs. 6 *a* & 6 *b*	Avonian	Gower	557
Caninia cornucopiæ, pl. xl, fig. 4		Burrington Combe & Stackpole Quay	373–74 556
—— aff. *cornucopiæ*, pl. xl, figs. 3 *a*–3 *c*		Gower	555–56
—— *cylindrica*, pl. xxxi, fig. 1		Burrington Combe	376–77
—— *patula*, pl. xxx, figs. 5 *a*–6 *b* & text-fig. 11			374–76
—— *(?)* sp., pl. xl, fig. 5		Gower	556–57
Carcinophyllum θ, pl. xxxi, fig. 5		Burrington Combe	377
Clisiophyllid, pl. xxxi, fig. 3			380–81

Name of Species.	Formation.	Locality.	Page
MADREPORARIA RUGOSA (*continued*).			
'*Cyathaxonia*' sp.	Avonian	Gower	558–59
Cyathophyllum murchisoni, pl. xxxi, fig. 6		Burrington Combe	379–80
—— (?) θ, pl. xxxi, fig. 2			379
Dibunophyllum θ & ψ, pl. xl, fig. 7		Gower	557–58
Diphyphyllum sp., pl. xxxi, fig. 7		Burrington Combe	380
Endophyllum burringtonense, sp. nov., pl. xxx, figs. 4 *a*–4 *c*			377–79
Michelinia konincki, nom. nov., pl. xxxi, fig. 4			372
—— *megastoma*			371
Streptelasma (?) aff. *breve*, pl. xxxvi, figs. 20 & 21	Powis-Castle Beds	Powis Park	455
Zaphrentis densa, pl. xxx, fig. 2	Avonian	Burrington Combe	373
—— *enniskilleni*, pl. xl, fig. 2.		Gower	554
—— *oystermouthensis*, sp. nov., pl. xl, figs. 1 *a*–1 *e* & text-figs. 9–10			553–55
—— cf. *parallela*, pl. xxx, figs. 1 *a*–1 *b* & (?) figs. 3 *a*–3 *b*		Burrington Combe	372
MADREPORARIA PERFORATA.			
Syringopora cf. *geniculata*	Avonian	Gower	553
ECHINOIDEA.			
Amphiope duffi sp. nov., pl. xlvii, figs. 2 & 3	Slonta Limestone	Ain Sciahat	667–68
Clypeaster biarritzensis, var. *trotteri* nov., pl. xlvii, figs. 1 *a* & 1 *b*	Upper Eocene	Cyrenaica	662–64
Echinolampas chericherensis, pl. xlviii, figs. 1 *a*, 1 *b*, & 2, pl. xlix, figs. 1–3			669–71
—— *discus*	*Operculina* Limestone		671
Euspatangus sp.	Aquitanian	Ain Sciahat	677
Fibularia luciani	Middle Eocene	Cyrenaica	664–65
Hemiaster scillæ	Aquitanian, etc.		673
Hypsoclypeus hemisphericus	Helvetian	Birlibah	671–73
Sarsella lamberti sp. nov., pl. xlviii, figs. 3 *a* & 3 *b*	Aquitanian	Cyrenaica	675–77
Schizaster ederi sp. nov., pl. xlvii, figs. 4 *a*–4 *c* & text-fig.			674–75
Scutella tenera	Lower Oligocene		665–66
—— sp.	(?) Miocene		666–67

Name of Species.	Formation.	Locality.	Page
OSTRACODA.			
Bairdia cf. *ampla (?)*, pl. xxvii, fig. 4	Coal Measures	Bristol District	325
Bollia lata	Gwern-y-brain Shales	N.E. Montgomeryshire	453
Ctenobolina cf. *ciliata*, pl. xxxvi, fig. 6			452
Estheria tenella, pl. xxvii, figs. 1 & 2	Coal Measures	Bristol District	324–25
—— cf. *tenella*, pl. xxvii, fig. 3			325
Jonesella crepidiformis, fig. 9 *c*	?	?	451–52
—— *obscura*, fig. 9 *a*			
Krausella arcuata	Gwern-y-brain Shales	N.E. Montgomeryshire	453
Loxoconcha cyrenaica sp. nov., text-fig.	Middle Eocene	Derna	660–61
Melanella hemidiscus, gen. et sp. nov., fig. 9 *b*	Gwern-y-brain Shales	N.E. Montgomeryshire	451–52
Primitia tumidula			452
—— *ulrichi*			452
Primitiella unicornis, pl. xxxvi, figs. 4 & 5			452
PHYLLOPODA.			
Leaia leidyi, var. *salteriana*, pl. xxvii, figs. 5 & 6	Coal Measures	Bristol District	325–26
TRILOBITA.			
Agnostus fallax, pl. xxv, figs. 17 *a*–18 *b*	*Paradoxides* Beds	Comley	291
Agraulos (?) holocephalus, pl. xxv, figs. 9 *a*–11 *c*			292
—— sp., cf. *quadrangularis*, pl. xxv, figs. 13, 14, & ? 15			292–93
Conocoryphe emarginata, var. *longifrons* nov., pl. xxiv, figs. 8–13			286–87
Dionide sp. *(?)*, pl. xxxvi, fig. 3	Trilobite-Dingle Shales	Guilsfield	450–51
Dorypyge lakei sp. nov., pl. xxv, figs. 1–8 & text-fig.	*Paradoxides* Beds	Comley	287–91
Microdiscus sp., cf. *punctatus*, pl. xxv, figs. 12 *a*–12 *c*			292
Paradoxides davidis, pl. xxiv, figs. 17 *a*, 17 *b*, & 18			285
—— *groomii*, pl. xxiii			283–85
—— *rugulosus*, pl. xxiv, figs. 14–16 *c*			286
—— spp. indet., pl. xxiv, figs. 1–7 *c*			285
Ptychoparia (Liostracus) dubia sp. nov., pl. xxv, figs. 19 *a*–21			295–96
—— *(——) pulchella* sp. nov., pl. xxvi, figs. 1 *a*–2			293–94
—— *(——)* sp. indet., pl. xxvi, figs. 3 *a*–3 *c*			295
Trinucleus intermedius sp. nov., pl. xxxvi, figs. 1 & 2	Trilobite-Diugle Shales	Welshpool	449–50

Name of Species.	Formation.	Locality.	Page
INSECTA.			
Archimylacris spp. indet., pl. vii, fig. 2 & pl. x, fig. 3	Coal Measures	Maes-y-cwmmer	152–53 163–65
—— *(Etoblattina) hastata* sp. nov., pl. ix, figs. 1–3			160–63
—— *(Schizoblatta) obovata* sp. nov., pl. vii, figs. 4–6			157–60
Genentomum subacutum sp. nov., pl. xxvii, figs. 18 & 19.		Bristol District.	334–36
Gerablattina (Aphthoroblattina) sulcata sp. nov., pl. viii, figs. 1–3		Maes-y-cwmmer	165–67
Hemimylacris convexa sp. nov., pl. vii, fig. 3		Clydach Valley.	156–57
—— *obtusa* sp. nov., pl. x, figs. 4 & 5		Penller-gaer	154–56
Lamproptilia tenuitegminata sp. nov., pl. x, fig. 6		Resolven	170–72
Orthomylacris lanceolata sp. nov., pl. x, figs. 1 & 2		Clydach Valley.	167–70
BRACHIOPODA.			
Acrothele cf. *granulata*, pl. xxvi, figs. 9 *a* & 9 *b*	*Paradoxides* Beds	Comley	302
Acrotreta (Linnarssonia) sagittalis, pl. xxvi, figs. 10 *a* & 10 *b*			302–303
—— aff. *socialis*, pl. xxvi, figs. 11 *a*–13 *b*			303
Athyris (Cliothyris) globularis, pl. xli, fig. 8 *a*	Avonian	Gower	564–65
—— (——) *roissyi*, pl. xli, fig. 8 *b*		Bristol (Avon)	564
Billingsella cobboldi sp. nov., pl. xxvi, figs. 20 *a*–23	*Paradoxides* Beds	Comley	305
—— *lindstrœmi* var., pl. xxvii, figs. 18 *a*–19 *b*			304–305
—— ——, var. *salopiensis* nov., pl. xxvi, figs. 14 *a*–17 *c*			303–304
Chonetes cf. *buchiana*	Avonian	Burrington Combe	381
—— cf. *comoides*			382–83
—— cf. *crassistria*			382
—— cf. *hardrensis*			382
—— cf. *laguessiana*			382
—— sp., pl. xli, figs. 3 *a* & 3 *b*		Gower	561
Daviesiella			561
Lingula mytiloides	Coal Measures	Bristol & Radstock	333
—— *obtusiformis*, sp. nov., pl. xxxvi, figs. 18 & 19	Gwern-y-brain Shales	Guilsfield	455

BRACHIOPODA (*continued*).

Name of Species.	Formation.	Locality.	Page
Lingulella cf. *ferruginea*, pl. xxvi, figs. 5–6 *b*	*Paradoxides* Beds	Comley	300-301
—— (?) spp. indet., pl. xxvi, figs. 7–8 *b*			301
Martinia glabra	Avonian	Gower	564
Orthis (*Orusia*) cf. *lenticularis*, pl. xxvi, figs. 24–26	*Paradoxides* Beds	Comley	306
—— (?) sp., pl. xxvi, figs. 27 *a* & 27 *b*			306
Orthotetes cf. *crenistria*, pl. xli, fig. 4	Avonian	Gower	561
Productus sulcatus, pl. xli, figs. 1 *a* & 1 *b*			559–60
—— (*Marginifera*) *longispinus*, var., pl. xli, figs. 2 *a* & 2 *b*			560
Spirifer bisulcatus, var. *oystermouthensis* nov., pl. xli, figs. 5 *a* & 5 *b*			562
—— *calcaratus*, pl. xli, fig. 5 *c*.		Pateley Bridge	562
—— near *increbescens*, pl. xli, fig. 6		Gower	562–63
—— *wickensis* sp. nov., pl. xli, fig. 7			563–64
Spiriferina cf. *octoplicata*		Burrington Combe	384–85
Syringothyris laminosa, pl. xxxi, fig. 8			383–84

LAMELLIBRANCHIATA.

Name of Species.	Formation.	Locality.	Page
Æquipecten camaretensis, pl. xlv, figs. 5 & 6	Aquitanian	Cyrenaica	633
—— *cyrenaicus* sp. nov., pl. xlvi, figs. 1 & 2	Prioabnian	Ain Sciahat	644–45
—— cf. *deletus*		Derna	644
—— *haueri*, pl. xliv, fig. 6	Aquitanian	Cyrenaica	634
—— cf. *pasinii*, pl. xliv, figs. 4 & 5			632
—— *scabrellus*			633–34
—— *zitteli*, pl. xlv, figs. 7 & 8.			632–33
Alectryonia cf. *plicatula*, pl. xliii, fig. 11	Helvetian-Tortonian	Gubah	626–27
—— cf. *virleti*		Benghazi	627
Anadara cf. *turonica*, pl. xliii, figs. 12 & 13		Cyrenaica	628
Anthracomya lanceolata, pl. xxvii, figs. 7–9	Coal Measures	Bristol & Radstock	329–30
—— *minima*, pl. xxvii, figs. 10–13			330–31
—— *phillipsi*			327–29
—— *williamsoni*		Radstock	327
Carbonicola sp.		Bristol district	327
Cardita sp.	Priabonian	Cyrenaica	649

Lamellibranchiata (*continued*).

Name of Species.	Formation.	Locality.	Page
Cardium tuberculatum	Post-Pliocene	Ptolemeta	625
Cerastoderma edule, pl. xliii, figs. 6, 9-10		Benghazi	621, 623–24
Corbis lamellosa, pl. xlv, figs. 12 & 13	Priabonian	Slonta district	648
Glycymeris glycymeris	Post-Pliocene	Benghazi	621
Jagonia pecten, pl. xliii, figs. 7 & 8			622
Loripes lacteus			622
Lucina cf. *nokbaensis*	Priabonian	Derna	647–48
—— cf. *pharaonis*		Cyrenaica	647
Luciniform casts	Aquitanian	Cyrenaica	636
Mactra cf. *fourtaui*	Priabonian		648–49
—— *stultorum*	Post-Pliocene	Benghazi	622
Naiadites elongata, pl. xxvii, fig. 14	Coal Measures	Bristol & Radstock	331
—— cf. *carinata*, pl. xxvii, fig. 15		Bristol district	332
Nucula oblonga, pl. xxvii, fig. 17			333
Oopecten rotundatus, pl. xliv, fig. 3	Aquitanian	Cyrenaica	634–35
Ostrea cf. *caudata*, pl. xliv, fig. 1		Slonta district	629–30
—— *crassicostata*, pl. xlv, figs. 1 & 2			630
—— *edulis*	Post-Pliocene	Benghazi	621
—— cf. *ventilabrum*, pl. xlv, figs. 9–11	Priabonian	Cyrenaica	642
—— sp. indet.	Lutetian	Ain Sciahat	650
Pecten arcuatus, pl. xlvi, figs. 3–6	Priabonian	Cyrenaica	643–44
—— *vezzanensis*, pl. xlv, figs. 3 & 4	Aquitanian	Ain Sciahat	631–32
—— *ziziniæ*	Helvetian-Tortonian	Benghazi	627–28
Pseudoedmondia (?) sp. nov., pl. xxvii, fig. 16	Upper Coal Measures	Radstock	332
Spondylus cisalpinus, pl. xliv, fig. 2	Aquitanian	Ain Sciahat	630–31
—— sp.	Priabonian	Slonta district	646
Trachycardium cf. *granconense*		Mersa Susa	646–47
Vulsella cf. *eymari*		Slonta district	645–46
—— sp.		Merj district	645

Gasteropoda.

Name of Species.	Formation.	Locality.	Page
Ampullina crassatina	Priabonian	Lamludeh	639–40
Bellerophon (Protowarthia) portlocki sp. nov., pl. xxxvi, figs. 10–12	Gaerfawr Grits	N.E. Montgomeryshire	453–54
Carinaropsis acuta, pl. xxxvi, figs. 13–15	Pwll-y-glo Beds.	Pwll-y-glo	454

GASTEROPODA (*continued*).

Name of Species.	Formation.	Locality.	Page
Cerithium cf. *vulgatum*	Post-Pliocene	Benghazi	620
Chelyconus mediterraneus			621
Columbella rustica			620
Cyclonema donaldi sp. nov., pl. xxxvi, figs. 7–9	Gaerfawr Grits	N.E. Montgomeryshire	453
Cyrtolites parvus, var. *carinatus* nov., pl. xxxvi, fig. 17	Trilobite-Dingle Shales.	Penbryn Dingle.	455
Eccyliomphalus contiguus, var. *cambrensis* nov., pl. xxxvi, fig. 16	Gwern-y-brain Shales	N.E. Montgomeryshire	454
Euspira cf. *possagnensis*, pl. xlvi, fig. 11	Priabonian	Cyrenaica	638–39
Gisortia gigantea, pl. xlvi, fig. 8		Mersa Susa	640–41
Helicella tuberculosa, pl. xliii, figs. 3–5	Post-Pliocene	Benghazi	620
Hygromia sordulenta, pl. xliii, figs. 1 & 2		Derna district	619
Rostellaria sp., pl. xlvi, fig. 10	Priabonian	Cyrenaica	640
Strombus cf. *coronatus*, pl. xliii, fig. 14	Helvetian-Tortonian	Gubah	626
Vasum cf. *frequens*, pl. xlvi, fig. 9	Priabonian	Messa	641

CEPHALOPODA.

Name of Species.	Formation.	Locality.	Page
Dimorphoceras (? discrepans)	Carboniferous	Exeter District	399–400
Glyphioceras beyrichianum			400–401
—— *crenistria*			406–407
—— *davisi*			403–404
—— *inconstans*			404–405
—— *phillipsi*			405
—— *reticulatum*			402–403
—— *sphæricum*			406
—— *spirale*			407–408
—— *striolatum*			401–402
? *Nomismoceras spirorbis*			408
Orthoceras koninckianum			409
—— *obtusum*			409–10
—— spp. *a* & *β*			410
Prolecanites (?) sp.			408–409

ELASMOBRANCHEI.

Name of Species.	Formation.	Locality.	Page
Ptychodus decurrens, pl. xvii, fig. 2, & pl. xix, figs. 20–24	Chalk	Various	264–65
—— —— var. *depressus*, pl. xvii, figs. 1 *a* & 1 *b*		Rochester district	266
—— —— var. *lævis*		....	267
—— —— var. *multistriatus*, pl. xviii, figs. 12–13, & pl. xix, figs. 6, 10, 12, 14		Various	267
—— —— var. *oweni*, pl. xviii, figs. 1–11, & pl. xix, fig. 8			266–67

Name of Species.	Formation.	Locality.	Page
ELASMOBRANCHEI (*continued*).			
Ptychodus dixoni sp. nov., pl. xx, figs. 1 & 2	Chalk	Rochester district	270–71
—— *latissimus*, pl. xx, figs. 3–5			270
—— *mammillaris*, pl. xxii, figs. 3–5		Cuxton & Betchworth	271–72
—— *mortoni*, pl. xxii, figs. 7 & 8		Winchester & Kansas	272–73
—— *polygyrus*, pl. xx, figs. 1–2 & pl. xxi, figs. 1–2		Various	268
—— —— var. *concentricus*		....	269
—— —— var. *marginalis*, pl. xxi, figs. 4 *a*–4 *c*		Rochester district	269
—— —— var. *sulcatus*		Various	270
—— *rugosus*, pl. xxii, figs. 6 *a* & 6 *b*		Purley & Chatham	272
MULTITUBERCULATA.			
Dipriodon valdensis sp. nov. (fig.)	Ashdown Sands.	Hastings	279–80
INCERTÆ SEDIS.			
Palæoxyris helicteroides, pl. xxvii, figs. 20 & 21	Lower Coal Measures	Bristol district	336
FUNGI.			
Palæachlya sp.	Aquitanian	Wadi Umzigga	659

EXPLANATION OF THE PLATES.

FOLDING TABLES.

PROCESS-BLOCKS AND OTHER ILLUSTRATIVE FIGURES,

BESIDES THOSE IN THE PLATES.

ERRATA.

Page 272, lines 6 & 26 from the top, and Page 275, line 4 from the bottom, for '*testitudinarium*,' read '*testudinarium*.'

Page 341, line 40 from the top, for '*Genentonum*,' read '*Genentomum*.'

Pages 451 & 452. Fig. 9 *b* alone represents *Melanella hemidiscus*, gen. et sp. nov.; and fig. 9 *a* represents *Jonesella obscura*, Ulrich.

Vol. LXVII. FEBRUARY, 1911. **No. 265.**
PART 1.

THE
QUARTERLY JOURNAL
OF THE
GEOLOGICAL SOCIETY.

EDITED BY

THE ASSISTANT-SECRETARY.

[With Ten Plates, illustrating Papers by Mr. L. Richardson, Mr. R. L. Sherlock, Dr. W. F. Hume, and Mr. H. Bolton.]

LONDON:

LONGMANS, GREEN, AND CO.

PARIS:—CHARLES KLINCKSIECK, 11 RUE DE LILLE.

SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

Price Five Shillings.

[Issued March 17th, 1911.]

LIST OF THE OFFICERS AND COUNCIL OF THE GEOLOGICAL SOCIETY OF LONDON.

Elected February 17th, 1911.

President.

Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.

Vice-Presidents.

Charles William Andrews, B.A., D.Sc., F.R.S.
Alfred Harker, M.A., F.R.S.
John Edward Marr, Sc.D., F.R.S.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.

Secretaries.

Prof. Edmund Johnston Garwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S.

Foreign Secretary.

Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.

Treasurer.

Aubrey Strahan, Sc.D., F.R.S.

COUNCIL.

Henry A. Allen.
Tempest Anderson, M.D., D.Sc.
Charles William Andrews, B.A., D.Sc., F.R.S.
Henry Howe Arnold-Bemrose, J.P., Sc.D.
George Barrow.
Prof. Thomas George Bonney, Sc.D., LL.D., F.R.S.
Prof. William S. Boulton, B.Sc.
James Vincent Elsden, D.Sc.
John Smith Flett, M.A., D.Sc.
Prof. Edmund Johnston Garwood, M.A.
Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.
Alfred Harker, M.A., F.R.S.
Robert Stansfield Herries, M.A.
Bedford McNeill, Assoc.R.S.M.
John Edward Marr, Sc.D., F.R.S.
George Thurland Prior, M.A., D.Sc.
Prof. Sidney Hugh Reynolds, M.A.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.
Aubrey Strahan, Sc.D., F.R.S.
Herbert Henry Thomas, M.A., B.Sc.
Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.
Rev. Henry Hoyte Winwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

Assistant-Secretary, Clerk, Librarian, and Curator.

L. L. Belinfante, M.Sc.

Assistants in Office, Library, and Museum.

W. Rupert Jones. Clyde H. Black.
Arthur Greig.

STANDING PUBLICATION COMMITTEE.

Prof. W. W. Watts, *President*.

Prof. E. J. Garwood, } *Secretaries.*
Dr. A. Smith Woodward, }

Mr. H. A. Allen.
Dr. C. W. Andrews.
Dr. J. V. Elsden.
Dr. J. S. Flett.
Mr. A. Harker.
Mr. R. S. Herries.
Dr. J. E. Marr.
Dr. G. T. Prior.
Prof. S. H. Reynolds.
Prof. W. J. Sollas.
Dr. A. Strahan.
Mr. H. H. Thomas.

EVENING MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

Session 1910–1911.

1911.

Wednesday, March 22
,, April .... 5*—26
,, May .... 10*—24
,, June 14*

[*Business will commence at Eight o'Clock precisely.*]

The dates marked with an asterisk are those on which the Council will meet.

THE
QUARTERLY JOURNAL
OF
THE GEOLOGICAL SOCIETY OF LONDON.

VOL. LXVII.

1. *The* RHÆTIC *and* CONTIGUOUS DEPOSITS *of* WEST, MID, *and* PART *of* EAST SOMERSET.[1]

By LINSDALL RICHARDSON, F.R.S.E., F.L.S., F.G.S. (Read November 9th, 1910.)

[PLATES I–IV.]

CONTENTS.

---

[1] In this paper, by 'West Somerset' is meant Somerset west of the Tone and Parrett; by 'Mid Somerset,' the portion between these rivers and a line running from the coast at Bream Down along the Mendip Hills to near Downhead, and then turning southwards; while 'East Somerset' is the remainder of the county.

I. INTRODUCTION.

IN Somerset the Rhætic rocks have a greater superficial extent than in any other county. It was anticipated that their investigation would prove of exceptional interest for several reasons: notably because—

(*a*) It has long been known that the Series attains an unusual thickness in places in this county, while it also frequently assumes a littoral facies when in contact with the Palæozoic rocks that formed land-areas during its time of deposition;

(*b*) The discovery in the top-portion of the 'Grey Marls' of Watchet of *Microlestes* teeth, associated with characteristic Rhætic fossils, has long been an important fact in the discussion as to whether the 'Grey and Tea-green Marls' (auctt.) should be classed with the Rhætic or with the Keuper;

(*c*) The *Pteria-contorta* Shales, with their associated hard beds, have yielded a rich assemblage of invertebrate fossils; and

(*d*) The White Lias is excellently developed, and its relationship to the Lower Lias can be studied in many sections.

In order, however, that students of the Series should have at their disposal easily-comprehended facts concerning the detailed stratigraphy, as also a knowledge of the position of certain strata bearing well-known names, and the horizons whence many of the well-preserved specimens now housed in our museums came, much detailed work was necessary. The main points that required to be settled were:—

(α) The stratigraphical position of the marls that had yielded the *Microlestes* teeth and other characteristic Rhætic fossils;

(β) The true position of the 'Wedmore Stone,' Moore's 'Flinty Bed,' and the *Pleurophorus* Bed;

(γ) Whether the 'Upper Rhætic' as developed, for example, at Garden Cliff, near Gloucester, is represented in Somerset; and

(δ) With which formation the White Lias proper is best classed—with the Rhætic, or with the Lias.

In addition to the record of a number of new or imperfectly described sections, my researches have resulted in showing that:—

(α) The *Microlestes* Marls correspond to the Sully Beds of the Glamorgan coast, and are well-developed in West Somerset;

(β) The *Pteria-contorta* Shales are of greater thickness than has generally been supposed, and contain, especially below the *Pleurophorus* Bed (13) and the main Bone-Bed (that is, Bed 15), some highly fossiliferous bands; that the 'Wedmore Stone' occurs well below the equivalent stratum to this main Bone-Bed (Bed 15); and that Moore's 'Flinty Bed' of Beer Crowcombe (or 'Crocombe' as it is now spelt) is most likely on the horizon of the *Pleurophorus* Bed (13);

(γ) The 'Upper Rhætic,' as defined in my previous papers, is as persistent as usual, if not quite so thick;

(δ) The White Lias proper is of considerable thickness in places, is in its characteristic development of comparatively restricted geographical extent, and is best classed with the Rhætic; and

(ε) That the marly beds above the White Lias proper, which correspond to similar marly beds at Lavernock (where they were provisionally grouped with the equivalent of the White Lias proper), are worthy of separation and distinct designation.

Indeed, it has become increasingly evident that, in order to be able to set forth clearly the changes in lithic structure which the Rhætic Series undergoes from place to place, and to convey to the palæontologist a knowledge of the horizons whence the fossils with which he may be dealing came, certain new stratigraphical terms are essential. These are discussed in a later portion of this paper.

(i) Geographical extent of the Rhætic Series.—The Rhætic beds have a greater superficial extent in this county than in any other, and their distribution is best seen upon reference to the Geological Survey maps.

(ii) On the lower and upper limits of the Rhætic Series.—In the Midland Counties the line of demarcation between the Keuper and the Rhætic is sharply defined[1]: the Tea-green Marls are succeeded suddenly by the well-known Black Shales. But in West Somerset, and in the Lavernock district on the opposite Glamorgan coast, there are, between the Tea-green Marls and the Black Shales, 'Grey Marls': real 'passage-beds,' for dark bands occur in them at more than one horizon and in their uppermost 14 feet or so—as Prof. Boyd Dawkins long ago pointed out[2]—characteristic Rhætic fossils make their appearance. For these top 14 feet of fossiliferous Grey Marls I have suggested the name of 'Sully Beds.'[3]

Although the gap between the Tea-green Marls and the Black Shales on the Bristol-Channel littoral is thus to a considerable extent bridged over by the intervention of the Grey Marls[4] and Sully Beds, there is still a non-sequence at the top—between the Sully Beds and the overlying Black Shales. The upper surface of the Sully Beds at Lavernock was deeply channelled before the deposition of the Black Shales[5]; while, both at St. Mary's-Well Bay (Sully) and at Lilstock, the top-layer of the Sully Beds is a thin band of impure limestone, practically made up of specimens of *Pteria contorta*, thus betokening slow formation. It is also interesting to note that other portions of the Sully Beds afford evidence

---

[1] E. Wilson, Q. J. G. S. vol. xxxviii (1882) p. 455; and Proc. Bristol Nat. Soc. ser. 3, vol. vii (1893–94) pp. 218 *et seqq.*

[2] Q. J. G. S. vol. xx (1864) pp. 397–98.

[3] *Ibid.* vol. lxi (1905) p. 386.

[4] In this paper the term 'Grey Marls' means those deposits, less the fossiliferous top-portion or Sully Beds. The term 'Grey and Tea-green Marls' means the Grey Marls, as thus defined, *plus* the Tea-green Marls, and in the record of a section indicates that I think that both those deposits in part or wholly are represented; while the usage of the term 'Tea-green Marls' alone implies that I think that there are no Grey Marls represented—only Tea-green Marls.

[5] Q. J. G. S. vol. lxi (1905) fig. 1, p. 390.

of slow formation, for Prof. Boyd Dawkins speaks of marks resembling sun-cracks and annelid-tracks in what I identify with the Sully Beds on the Watchet coast.[1]

So far as can be deduced from a study of the lithic and faunal characters of the lower beds of the Black-Shale division and their relationship to the Keuper Marls, the area of sedimentation in closing Triassic times seems to have become continuously smaller and to have been situated in the South-West of England. The commencement of the changes in surface-level, which initiated Rhætic conditions, are probably indicated by the occurrence of black marls in the Grey Marls; while, just before crust-movements effected the restriction of the area of sedimentation to the neighbourhood of the present Bristol-Channel littoral, the pioneers of the Rhætic fauna must have obtained entrance. Their scanty remains are preserved in the Sully Beds, and the period of minimum submergence is probably marked by the runnelled surface of the Sully Beds and the closely-packed layer of specimens of *Pteria contorta*. Gradual submergence then set in, and the neighbourhood of the present Bristol Channel received the earliest deposits of the Black-Shale division.

Thus, while over the greater part of England the lower limit of the Rhætic Series is sharply defined, because the Sully Beds and a greater or less thickness of the Black-Shale division are absent, and there is therefore a non-sequence, on the Bristol-Channel littoral it is most unfortunately indefinite—being determined by the downward range into the Grey Marls of Rhætic fossils. For scientific purposes, the Sully Beds must be grouped with the Rhætic; but for cartographical purposes—as I have before endeavoured to make clear[2]—they must be grouped with the Keuper Marls.

As regards the upper limit of the Rhætic Series, in most parts of the South-West of England it is fairly definite. The Lower Liassic beds which are generally grouped together as the *Ostrea* Beds are readily recognized, and underlying them is often present a band of hard 'paper-shales.' The Paper-Shales are not always present; but the *Ostrea* Beds have a wide geographical extent, and rest in different places upon different members of the underlying Rhætic Series. Thus, near Wickwar, they rest upon the Cotham Marble; but in the Charlton-Mackrell district there is very clearly interposed between them and the Cotham Marble the White Lias proper; at Blue Anchor Point in West Somerset, both the reduced equivalent of the White Lias proper and certain marly beds ('Watchet Beds,' see p. 15) above; while at Camel Hill, Moore's Insect- and Crustacean Beds come in at a higher horizon.

There is thus generally a non-sequence between the Rhætic and the Lias, which implies that, as a rule, the two series are well marked off one from the other.

---

[1] Q. J. G. S. vol. xx (1864) p. 398.

[2] *Ibid.* vol. lxi (1905) p. 414; and Proc. Geol. Assoc. vol. xix (1906) p. 403.

II. SUBDIVISIONS RECOGNIZABLE IN THE RHÆTIC ROCKS OF THE DISTRICT DESCRIBED.

The beds that lie between the Keuper and the Lias constitute the Rhætic Series. The Series admits of dual division—into Upper and Lower Rhætic.[1] The Sully Beds and Black-Shale subdivision, or the 'Zone of *Avicula* [*Pteria*] *contorta*' of earlier authors, constitute the Lower Rhætic; while the 'Upper Rhætic' of my previous papers, the White Lias proper and certain immediately-superincumbent marly beds ('Watchet Beds,' see p. 8), compose the Upper Rhætic as now defined. These two primary subdivisions are very distinct one from the other, both as regards lithic structure and as regards faunal characters.

Lower Rhætic.

Sully Beds.—Concerning these beds almost sufficient has been said. The essential points to remember are that in reality they are only the topmost 14 feet or so of the Grey Marls that contain Rhætic fossils.[2] Their upper surface in places shows evidence of channelling by water previous to the deposition of the Black Shales, and this fact—among others—points to a non-sequence, which largely explains the difference in appearance between the Sully Beds and the succeeding Black Shales.

Westbury Beds.—This term is suggested for use, as an alternative term to 'Black Shales,' etc.

The Westbury Beds vary considerably in thickness in this country: at Berrow Hill, near Tewkesbury, they are but 9 feet thick; at Lilstock, 32 feet; and at Blue Anchor, near Watchet, they may be as much as 46 feet thick. In other localities they are thinner, but nowhere thicker. It is interesting to note that, where the Westbury Beds are thick, so are the subjacent Tea-green Marls or Tea-green and Grey Marls, and *vice versa*.

The Westbury Beds were deposited not far from the coast-line, for this is shown by their Swabian or littoral facies. The mollusca have a dwarfed appearance: gastropods are abundant in certain beds in Somerset, and in the sandstone of Pylle (Glamorganshire) specimens of *Natica* abound; pieces of lignite are not infrequent in some of the beds in Glamorgan and Somerset; and, except for *Orbiculoidea townshendi* (Forbes), brachiopods are wanting.

---

[1] [Certain other terms were suggested for these subdivisions when the paper was communicated (see Discussion, p. 73); but, in deference to the wishes of the Publication Committee, those terms are not used here.]

[2] In places in West Somerset Prof. Boyd Dawkins also found characteristic Rhætic fossils in some abundance in the Grey Marls that are now correlated with the Sully Beds. (Q. J. G. S. vol. xx, 1864, pp. 397 *et seqq.*)

Roughly speaking, the Westbury Beds can be separated into two parts, an upper and a lower, according to the occurrence of vertebrate and invertebrate remains respectively, for vertebrate remains abound in the beds from the horizon of Bed 15 (that is, the main Bone-Bed or its equivalent) downwards; while invertebrate remains predominate in that portion of the Westbury Beds which lies above Bed 15.

Beds containing an abundance of vertebrate remains occur at several horizons in the Westbury Beds; but one stratum, that which I have numbered 15 in my various sections, I regard as a contemporaneous deposit. *Ceratodus* teeth are abundant in it at Aust Cliff; they have also been recorded from the equivalent stratum at Garden Cliff, near Gloucester, and at Blue Anchor Point in West Somerset. Indeed, the teeth of this fish might almost be looked upon as zonal fossils.

At Aust Cliff the Bone-Bed (15) rests directly upon the Tea-green Marls, and contains rounded lumps of that subjacent rock. But at Blue Anchor it is separated therefrom by 22 feet of Westbury Beds, 14 feet or so of Sully Beds, and about 80 feet of Grey Marls.

The deposits that belong to the Westbury Beds and occur below Bed 15 in the Watchet district include a number of nodular limestones with a most interesting series of invertebrate fossils—among them being excellently-preserved specimens of *Pteromya crowcombeia* Moore, and other rarities.

The sections near Watchet have long been known to be more than usually rich in fossils, the comparative scarcity of which, if not their absence elsewhere, was a matter for investigation. Now, however, it will be seen that there is a series of beds below Bed 15, 'infra-Bone-Bed deposits' they may be called, in the Watchet district, which is not equalled elsewhere in the country.

North of Aust, at Garden Cliff, infra-Bone-Bed deposits are again in evidence; but their geographical distribution to the north, as shown by sections along their outcrop, is not extensive, and was probably governed by earth-movements anterior in date to their time of deposition.

As regards the Westbury Beds above Bed 15, the following points should be noticed:—

(1) The *Pleurophorus* Bed is a useful horizon, is frequently of bone-bed nature, in West Somerset is crowded with gastropods, and is probably the bed that, at Beer Crocombe, Moore called the 'Flinty Bed';

(2) Between the maxima of *Pteria contorta* and *Chlamys valoniensis* there is generally a rather barren deposit of shale;

(3) The horizon of the maximum of *Chlamys valoniensis* is generally marked by one or more limestone-beds;

(4) Somewhere about a foot below Bed 7 is the niveau of the ophiuroid *Ophiolepis damesi*;

(5) The *Cardium-cloacinum* Bed is well characterized by *Cardium cloacinum* Qu., and affords an excellent datum-level for correlating sections on the Bristol-Channel littoral.

Thus, while the Westbury Beds above Bed 15 can be correlated, as regards their component deposits, very tolerably, the same remark does not apply to those below that bed.

The black shales of the Westbury Beds in this country usually give place somewhat suddenly to pale marls and equally pale associated limestones. The difference in lithic structure between the Westbury Beds and these succeeding 'Cotham Beds,' as they may be called, is nothing as compared with the difference in faunas. These dissimilarities suggest interruption in sequential deposition, and the probability of such interruption is seen when the beds near the junction-line of the two subdivisions are studied. In the railway-cuttings at Sparkford Hill and Charlton Mackrell the great boulder-like masses of stone at the top of the Black Shales point in the same direction as does the interesting discontinuity of the pale greenish-grey deposit at the base of the Cotham Beds at St. Audrie's Slip, near Watchet. The causes producing these phenomena effected the initiation of conditions suitable for the formation of the pale deposits which—as already remarked—may be called the 'Cotham Beds,' with their interesting assemblage comprising *Estheriæ*, ostracoda, and *Lycopodites*.[1]

Upper Rhætic.

Cotham Beds.—The succeeding division of the Rhætic Series, the 'Upper Rhætic' of my former papers, or the 'Cotham Beds,'[2] differs (as already hinted) considerably from the one which it overlies. The component deposits are very different, and so too is the fauna. Pale marls and limestones largely compose it, and at certain horizons ostracoda, plant-remains, and *Estheriæ* are abundant. The bed in which the *Estheriæ* and plant-remains mainly occur in Worcestershire and North-West Gloucestershire is a well-marked limestone with arborescent markings, and, except for the *Pseudomonotis* Bed or its equivalent, is the only limestone in the Cotham Beds. But, from the neighbourhood of Chipping Sodbury southwards to that of Bristol, there are usually a number of impure argillaceous limestone-bands in the Cotham Beds, and phyllopods, as also remains of lycopods, occur at several horizons; while over the greater part of Somerset there are at least two noticeable limestone-bands, in addition to the Cotham Marble or its equivalent. Ostracods are most abundant immediately below the *Estheria* Bed, but occur also in the marls above. The Cotham Marble is frequently rich in specimens of *Pseudomonotis fallax*; and, of course, in the *Pseudomonotis* Bed of Garden Cliff such specimens

---

[1] *Lycopodites* and *Estheriæ* have not been discovered, so far as I am aware, south of the Mendip Hills. Hapsford Mills in Vallis Vale is the southernmost place at which I have obtained them.

[2] After Cotham, near Bristol, where the Cotham Marble is well-developed.

abound, literally covering the surfaces of the thin pieces of limestone that can be there split off from the bed.

The main point to notice, however, so far as Somerset is concerned, is that the Cotham Beds are persistent south of the Mendip Hills, if not quite so thick as in North-West Gloucestershire, and divide the Black Shales (Westbury Beds) from the White Lias proper (Langport Beds).

Langport Beds.—The change from Cotham Beds to Langport Beds is considerable, palæontologically more than lithically. In other words, some pause in the normal sequence of deposit is again suggested. The frequently *Lithophagus*-bored and *Dimyodon*-encrusted nodules of Cotham Marble, as at Dundon Hill (p. 39); the 'false' or conglomeratic Cotham Marble of Culverhole, Somerton, Sedbury Cliff, Aust Cliff, etc.; the remarkable relationship of the Cotham-Marble equivalent to the Langport Beds at Lilstock, are all facts which point to a temporary interruption of sequential deposition, connected doubtless with the causes that brought about the conditions suitable for the formation of the richly-fossiliferous Langport Beds or the well-known White Lias proper.

In Somerset, in the fine section in the railway-cutting at Charlton Mackrell, where the Langport Beds were so magnificently exposed, they were separable into five groups. The first and top one embraced the 'Sun'- and 'Block-Beds'; the second, the 'Rubbly Beds' and three massive limestones; the third, more regularly-bedded limestones; the fourth, similar beds, but with a massive top-bed, often coralliferous (*Thecosmilia ? michelini* Terq. & Piette); and the fifth, very massive limestones, locally called 'the Sizes.' The mammillated and often bored upper surfaces of the Sizes, together with their irregular nether surfaces; the irregular, rubbly, and conchoidal fracturing of many of the other beds; and the way in which the fossils are attached to the upper surfaces of the limestones or are embedded in the marl, all bear witness to the slow rate at which the Langport Beds were formed.

Dimyodon intus-striatus, which makes its first appearance in the *Pteria-contorta* Shales and is usually absent from the Cotham Beds, appears in great force. Moreover, specimens of *Volsella minima* (Moore *non* Sow.), *Ostrea liassica*, *Plagiostoma valoniense*, and in places internal casts of *Cardinia* and *Protocardia* abound, but do not appear to be of any use zonally.

Watchet Beds.—These beds have a very restricted geographical extent: it is approximately coextensive with that over which the Sully Beds were laid down. They are not very interesting, comprising marls with inconspicuous and impure limestone-layers, that contain occasional specimens of *Ostrea liassica* Strickland and *Volsella minima* (Moore *non* Sow.). They are distinct from the Langport Beds, decreasing in thickness eastwards as those increase, and also from the Lower Lias that overlies them.

Lower Lias.

Above the Watchet Beds come the 'Paper-Shales' of the Lower Lias and the *Ostrea* Beds. The Paper-Shales are very distinct from the underlying Watchet Beds, and it may be that in between is the stratigraphical position of Moore's 'Insect- and Crustacean Beds': beds which are well-developed at Camel Hill. It is pleasing to find that this careful stratigrapher, Charles Moore, held that these beds were often absent; but he did not sufficiently emphasize the point. In many parts of Somerset, as at Curry Rivel and on the Nempnet outliers north of the Mendip Hills, the top-bed of the Langport Beds is pierced by annelid-like perforations. The immediately superincumbent strata are generally the *Ostrea* Beds, and the perforations furnish evidence of a non-sequence.

Thus it appears that the reason why the several subdivisions of the Rhætic are so well marked off one from the other, both as regards faunal and as regards lithic characters, is because generally they are non-sequentially related. A study of the English Rhætic supports Suess's statement that, while the dominant movement was one of subsidence and not local but extended, it was, nevertheless, not a sudden event, 'but oscillatory and slow.'[1]

The following table will show at a glance the classification of the Rhætic Series followed in this paper; its relationship to the old arrangement; and also the thicknesses of the several stages of deposit, as noted in the South-West of England—between Gloucester and the English Channel.

TABLE I.—CLASSIFICATION OF THE RHÆTIC SERIES.

LIAS.	LOWER.	*Ostrea* Beds, etc.	*Approximate thicknesses in England.*
RHÆTIC	UPPER	I. Watchet Beds ('Marly Beds of the White Lias') ………	0 to 7 ft. 7. ins.
		II. Langport Beds (White Lias proper) ………	0 to 25 feet.
		III. Cotham Beds ('Upper Rhætic') ………	2 ft. 9 ins. to 19 ft.
	LOWER	IV. Westbury Beds (Black Shales)	1 to (?) 47 feet.
		V. Sully Beds (Fossiliferous Grey Marls) ………	0 to 14 feet.
KEUPER	UPPER	Grey and Tea-green Marls ………	about 11 to 115 feet.
		Red Marls.	

The sequence of maxima of notable fossils has been inserted in Table II (p. 10).

---

[1] 'The Face of the Earth' (Transl. H. B. C. Sollas) vol. ii (1906) p. 268.

Table II.—Comparative Synopsis of the Deposits at Lavernock and in West Somerset; and Sequence of the Maxima of the principal Fossils of the Rhætic.

	Deposits.	Lavernock.			Blue Anchor.			St. Audrie's.			Lilstock.			Sequence of the maxima of the principal fossils of the Rhætic.	
		Ft.	ins.		Ft.	ins.		Ft.	ins.		Ft.	ins.			
Lower Lias.	Paper-Shales (and occasional limestone at the base).	1	0		1	0		1	0		1	0		*Volsella* sp., etc.	
Upper Rhætic.	Watchet Beds.	6	4		7	7		4	10		4	10		*Ostrea liassica.* *Volsella minima* (Moore *non* Sow.). *Dimyodon intus-striatus.* *Pseudomonotis fallax.* Ostracoda. *Estheriæ* & *Lycopodites.* Ostracoda common below Bed 3.	
	Langport Beds.	2	6		2	3		4	2		3	11			
	1. Cotham Marble.	Absent.			Cotham Marble, 6″.			[Cotham Marble.]			Cotham Marble, 3″.				
	2. …………				4	10		7	8		5	8			
	3. …………														
	4.	2	9												
Lower Rhætic.	5 *a.*	5	6	20 ft. 10 ins.	3	5	46 ft. 3½ ins.	6	1	33 ft. about.	5	10	32 ft.	*Cardium cloacinum.* *Actæonina* & *Natica oppeli.*	*Contorta*-Age.
	5 *b. Cardium-cloacinum* Bed	0	3		0	6		0	3		Not recognized				
	6.	9	3		18	4½		14	1		14	4½			
	7. *Pecten* Bed.													*Chlamys valoniensis.*	
	8.													*Ophiolepis damesi.*	
	9.														
	10.													*Pteria contorta.*	
	11.														
	12.														
	13. *Pleurophorus* Bed.	Not recognized.			0	4		0	8		0	3		*Pleurophorus elongatus.* '*Chemnitzia*' spp.	
	14.	1	1		1	1		1	6		1	6		Relatively barren.	
	15. Bone-Bed.	0	9		0	6		0	5		0	6		*Ceratodus latissimus.* *Mytilus cloacinus.*	
	Infra-Bone-Bed deposit.	4	0		22	0		10	0		9	6½		Vertebrate remains (*Acrodus minimus*, etc.).	
	Sully Beds.	14	0		13	1		5	0+		7	9		*Ostrea bristovi.*	
Keuper.	Tea-green and Grey Marls.	33	4		111	0									

III. Local Details.

(1) West Somerset.

In West Somerset Rhætic deposits occur in two tracts: the one a small outlier capped with Lower Lias at Selworthy; and the other in the comparatively long stretch of country alongside the coast, extending from Blue Anchor Point to the Parrett at Combwich.

(A) The Selworthy Outlier.

Rhætic beds are not now visible in this outlier; but, since the ordinary Red Keuper Marls are to be seen in the bank of the Porlock Road, and the *Ostrea* Beds are worked in the wood at the turning out of the main road for Blackford, there is no reason to think that they are otherwise than normally developed, although very probably not so thickly as at Blue Anchor.

Etheridge has referred to some section in this outlier, which was open when he visited this neighbourhood about 1870, as the 'Lower Venniford' section[1]; but he gives no details concerning it, and I have not been able to locate it.

(B) The Watchet Area.

(i) Introduction.—The Watchet area is best known in connexion with the discovery, by Prof. Boyd Dawkins, of the teeth of the earliest-known mammal, *Microlestes rhæticus*, at a distance of 10½ feet down in the marls that were then called the 'Grey Marls.'[2]

The Bone-Bed at Blue Anchor was first discovered by one Robert Anstice, who obtained a considerable number of vertebrate remains therefrom,[3] and attention was again drawn to it in 1860 by Thomas Wright.[4]

Then came Prof. Boyd Dawkins's paper in 1864[5]; which was followed by one from Etheridge entitled 'Notes upon the Physical Structure of the Watchett Area, & the Relation of the Secondary Rocks to the Devonian Series of West Somerset.'[6] He discusses the St.-Audrie's-Slip and railway-cutting sections 'south of Watchett' in some detail; and refers to that at 'Little Stoke' (Lilstock), but there is no mention of that at Blue Anchor.

On Sheet 47 of the Vertical Sections, published by the Geological Survey, is a record of the St.-Audrie's-Slip section by Bristow & Etheridge (1873).

In 1896 the Geologists' Association visited the neighbourhood, and a paper, of the nature of a résumé, was written for use on

---

[1] Proc. Cotteswold Nat. F. C. vol. vi (1871–77) p. 37.

[2] Q. J. G. S. vol. xx (1864) pp. 397–402.

[3] Trans. Geol. Soc. ser. 2, vol. i (1824) p. 301.

[4] Q. J. G. S. vol. xvi (1860) p. 384.

[5] *Ibid.* vol. xx, pp. 397–402.

[6] Proc. Cotteswold Nat. F. C. vol. vi (1871–77) pp. 35–48.

the excursion by the Rev. H. H. Winwood,[1] who also revised the subsequent 'report.'[2]

In 1905, in a footnote to my remarks on the Sully Beds at Lavernock, I mentioned that I had identified the Sully Beds on the Watchet coast [3]; but it did not have the effect of directing the attention of the authors of the Geological Survey Memoir on 'The Geology of the Quantock Hills, & of Taunton & Bridgwater,' issued some three years later, to the beds. In this memoir Bristow & Etheridge's section at St. Audrie's Slip is summarized and reproduced with some slight additions and emendations, and the same remark applies to Prof. Boyd Dawkins's section 'about a quarter of a mile east of Watchet Harbour.' Except for a section 'in a quarry between Hill Farm and Beere Farm west of Combwich,' which is diagrammatically represented, there is no additional information requiring particular notice here.[4]

It is indeed strange that the fine sections in the foreshore and cliffs at Blue Anchor and Lilstock (Little Stoke, auctt.) should have received practically no attention; but probably the cause lies in the comparative inaccessibility of the neighbourhood.

(ii) Stratigraphical Details.

Coast from Blue Anchor to Watchet.—In this part of the area the Rhætic deposits have been bent into a slight anticline, and have been let down between two faults: one inshore, and the other far out in the foreshore.

The photograph reproduced in Pl. I will give an idea of this slight anticlinal arrangement of the beds. The Rhætic deposits, high up in the cliff, were, of course, once continuous over the axis of the anticline; but, while they have been removed therefrom, they may be seen again in the foreshore dipping Channelwards—the hard beds giving rise to prominent ledges (Pl. II).

The junction of the Red with the Tea-green and Grey Marls is seen in the interesting 'Warren Farm Section' in Cleeve Bay, a short distance eastwards along the coast from Blue Anchor Point. Fig. 1 (p. 13) shows the position of this section, and Pl. IV makes clear the arrangement of the beds. In this section, Beds 22 *a* to 12 are to be seen—the actual junction of the Tea-green and Grey Marls with the Red being displayed to the right of the observer, when he stands facing the section depicted in Pl. IV.

Returning to Blue Anchor Point (Pl. I), the two prominent bands of marlstone near the base constitute Bed 20 of the record on p. 20. In Pl. III, fig. 2, is reproduced a photograph of the Keuper Marls, with their bands and veins of gypsum, from this Bed 20 up to Bed 11; while descriptive details will be found on pp. 19–20.

The uppermost beds of the Keuper, the Sully Beds, and the lower portion of the Westbury Beds are very difficult of access at Blue Anchor Point. Fortunately, however, several other sections are available.

---

[1] Proc. Geol. Assoc. vol. xiv (1896) pp. 378–88.

[2] *Ibid.* pp. 433–36.

[3] Q. J. G. S. vol. lxi (1905) p. 389.

[4] *Op. cit.* Mem. Geol. Surv. pp. 65–71.

On turning the Point, the first gypsum-workings will be seen.[1] A path leads from these workings to the top of the cliff; and, about half-way up it, the *Pteria-contorta* Shales will be noticed in the bank alongside the track. On the right is a steep, but (owing in places to the talus) accessible, face of rock in which the uppermost portion of the Sully Beds, and Beds 33 to 26 of the Westbury Beds, can be made out. The hard, grey-blue, nodular limestone-masses, called 'The Clough,' are very conspicuous.

Fig. 1.—*View of Cleeve Bay looking towards the North Hill, Minehead.*

L. R. photogr.

[To show the position of the Warren-Farm section on the shore-line where a line connecting the two arrows would strike it.]

Down on the foreshore, opposite these gypsum-workings, the continuations of the same beds, that is of Beds 33 to 26, along with higher deposits, up to and inclusive of the *Pleurophorus* Bed, Bed 13, can be readily identified. The basal deposit of the Westbury Beds (Bed 33) contains small nodules, derived from the subjacent Sully Beds, which weather out very conspicuously, as do also the contained coprolites and fish-remains. In this section the 'nodules' occur in a regular course, and are parted from the Sully Beds by an inch or two of black marl; but, in the next section to be noticed, they are seen to be more intimately connected with the basal bone-bed. 'The Clough' is interesting, because it is its nodules that are principally sought for on the shore, placed in baskets on the backs of donkeys, and taken to the lime-kilns for burning, as they make the best lime.

---

[1] Proc. Geol. Assoc. vol. xiv (1896) p. 384.

The next section, also in the foreshore, is that depicted in Pl. II. Here each individual layer can be readily investigated and searched for fossils, which are abundant—especially in the *Pleurophorus* Bed—and well-preserved. It was here that the details recorded on p. 17, under the heading 'Foreshore Section near the First Gypsum-workings,' were obtained, and the numbers in Pl. II correspond to those tabulated in that record.

It is unfortunate that it has not been possible to connect the last section with that exposed at Blue Anchor Point, where the beds are accessible again; but, as already remarked, the Blue-Anchor-Point section is a very difficult one to examine, and the investigation of the higher beds is not unattended by actual danger.

The main Bone-Bed (15) was not visible in the Point section when I visited the locality; but I procured some excellent specimens loose on the cliff-slope, by working along in the direction of the Point from the section by the path-side near the gypsum-workings. Typically, the bed is a very hard, grey, compact siliceous sandstone, crowded with fish-scales and teeth and occasional fragments of bone. The surface of the main bed, where it rises along the foreshore forming that conspicuous reef (Pl. II), has a distinctly gritty appearance—the grains weathering out very distinctly along with the vertebrate remains. But the bed is subject to some variation for, by the pieces picked up on the cliff-side, it is seen to comprise several layers, the topmost of which consists, in its upper part, of the same kind of siliceous material as that in the foreshore, but dull greyish-blue, rarely vertebratiferous limestone in its lower. Occasionally the uppermost layer also is shelly, containing indeterminable examples of a species of *Isocyprina*.

The Bone-Bed of Blue Anchor is probably on the horizon of the series of beds included under 15 at Lavernock Point. At Lavernock, strange to say, there is no distinctive *Pleurophorus* Bed. Where it is to be presumed that it should come is a marked line in a black-shale deposit, with thickly-laminated shales below and thinly-laminated shales above. Then comes Bed 9—a limestone-band, frequently nodular, which (there can be little doubt) is correlative with a similarly-numbered bed at Lilstock and in the railway-cutting at Charlton Mackrell. Shales, quite twice as thick as at Lavernock, separate from Bed 5 *b* the limestone which I consider to be on the horizon of Bed 9.

The identification of Bed 5 *b* at Blue Anchor Point is very important, as it affords a sure datum-level for correlative purposes, connecting this section with that at Bishton, near Newport (Mon.), and with that at St. Audrie's Slip to the east of Watchet. As regards lithic structure, it is difficult to separate hand-specimens of the bed from these three localities, and the principal fossils occur in about the same proportion, as regards numbers, at the several localities named.

At Lavernock Point, where I measured the section which I have published,[1] there is a non-sequence between the 'White Lias' and

---

[1] Q. J. G. S. vol. lxi (1905) table facing p. 392.

the 'Cotham Beds'—the lowest bed of the 'White Lias' there rests non-sequentially upon the lower portion of the bottom deposits of the Cotham Beds, which have been partly eroded and fissured, and the cracks filled up with gritty material, before the lowest bed of the 'White Lias' there present was laid down. Here at Blue Anchor, however, the Cotham Beds are complete. The 'White Lias' or Langport Beds of Blue-Anchor and Lavernock Points correspond remarkably well, as the numbers in square brackets (below), which refer to Lavernock, are intended to indicate.

The shales, which I lettered A at Lavernock and grouped provisionally with the 'White Lias,' are represented by an increased thickness of similar deposit at Blue Anchor Point, and I have suggested that they shall bear the name of 'Watchet Beds.' They are succeeded at Blue Anchor, as at Lavernock Point, by those very distinctive hard brown shales for which the name of 'Paper-Shales' is so appropriate—occasionally hardened at the base to simulate a limestone-band. Then comes that massive limestone which doubtless corresponds to the 'Bottom-Lias' bed at Dunball (p. 33).

SECTION AT BLUE ANCHOR POINT, NEAR WATCHET.

				Thickness in feet	*inches.*	
LOWER LIAS.			'Bottom Lias.' Limestone, hard, blue, but shattered			*Ostrea liassica* Strickland.
			Shales, hard, pale-grey and brown, becoming compact and passing down into a fissile	0	9	= Paper-Shales.
			Limestone, which is not always conspicuous	0	3	
UPPER RHÆTIC.	WATCHET BEDS.	1.	Shales, well-laminated, brownish-yellow, with a few thin layers of gritty limestone, one especially noticeable at 11 inches above Bed 2; about	4	2	
		2.	Marl, yellowish, sandy in appearance	0	4	
		3.	Shales, hard, brown, laminated, with thin layers of fibrous calcite	1	2	
		4.	Shales, bluish-grey, not very well laminated	1	2	*Ostrea liassica* common at the top.
		5.	Limestone, bluish-grey, weathering pale-brown, but often not very conspicuous: 2 to 4 inches	0	2	*Ostrea liassica.*
		6.	Marl, bluish-grey, laminated: 3 to 4 inches	0	3	Fragment of *Ostrea*, *Dimyodon intus-striatus* (Emmerich), *Chlamys* (sp. indet.).
		7.	Limestone, hard, pale-brown and bluish-grey centred	0	1	
		8.	Marl, brown	0	3	
				7	7	
	LANGPORT BEDS.	1–3 [B]	Limestone, hard, greyish-brown, shelly, conchoidal fracture. At the base, which is very uneven, are lumps of a more compact and paler limestone	0	7	*Ostrea liassica* (common), *Dimyodon intus-striatus.*
		[C] 4 [1–3]	Marl, brownish-grey	0	7	
		5 [4]	Limestone, often absent, brown and greenish-grey, earthy: 0 to 1 inch	0	1	*Dimyodon intus-striatus*, *Protocardia rhætica* (Merian).
		6 to 8 [5 to 7]	Marl, pale-brown with a thin limestone at the base.	0	4	
		9 [8]	Limestone, brown, earthy	0	5½	
		10 [9]	Marl, brownish	0	1½	
		11 [10]	Limestone, hard, bluish-grey, conchoidal fracture	0	1	Shell-débris.
				2	3	

Division	Beds	No.	Sub-bed	[Blue Anchor Point.]	*Thickness in feet*	*inches.*	Fossils
UPPER RHÆTIC (*continued*).	COTHAM BEDS.			Shales, dark-brown	0	4	
		1.		Cotham-Marble equivalent: 1 to 3 inches	0	2	
		2.		Shales, greenish-grey, calcareous ...	1	0	Ostracods at the top.
		3.		Limestone, pale-brown, blue-centred	0	4	
		4.	(1)	Shales, greenish-grey, with thin layers of a pale-green limestone full of shell-débris. The deposit from the base up to 8 inches therefrom (and of a brown tint) is closely packed with thin limestone-layers, so as to constitute in places a compact stratum, which is separated from the underlying bed by more shaly matter	2	0	
			(2)	Limestone, pale greenish-grey, on the whole a conspicuous and massive bed, including at the base a bluish-grey limestone 3 inches thick: 14 to 16 inches	1	3	
			(3)	Marl, brown, clayey: 2 to 3 inches.	0	3	
					5	4	
LOWER RHÆTIC.	WESTBURY BEDS.	5*a*.	(1)	Shales, black, with thin brown seams	0	7	
				Conspicuous brown shelly seam and 'beef'	0	1	
				Shales, black, very fossiliferous at the base: 10 to 16 inches ...	1	1	*Pteria contorta* (Portlock), *Chlamys valoniensis* (Defrance), *Dimyodon intus-striatus* (Emmerich).
			(2)	Limestone, blackish, pyritic, with a $1\frac{1}{2}$-inch layer of 'beef' on the top. Much black shale is mixed with the limestone. Very pyritic in places, and when decomposed is of a rich reddish-brown	0	2	*Chlamys valoniensis, Dimyodon intus-striatus.*
			(3)	Shales, black, laminated: 18 inches to 2 feet	1	6	In the top portion of this deposit *Chlamys valoniensis* and *Pteria contorta* are common; *Placunopsis alpina* (Winkler).
		5*b*.		*Cardium-cloacinum* Bed. Limestones, thin, very dark-grey, with shale-partings, associated with nodules of pale-grey hard limestone — the *Cardium-cloacinum* Bed proper	0	6	*Cardium cloacinum* Quenstedt, *Protocardia rhætica* (Merian), *Pteria contorta, Placunopsis alpina, Ostrea* sp.
		6.	(1)	Shales, black, with thin limestone-layers intercalated among them near the base and containing many fossils	2	3	*Pteria contorta, Chlamys valoniensis, Placunopsis alpina* (large), *Pleurophorus elongatus* Moore, *Dimyodon intus-striatus, Protocardia rhætica, Volsella minuta* (Goldfuss).
			(2)	Limestone, blackish, mixed with shale, and extremely fossiliferous.	0	2	
			(3)	Shales, black	0	$2\frac{1}{2}$	
			(4)	Shales, earthy, black, calcareous, bound together by 'beef' so as to resemble a hard bed	0	7	*Chlamys valoniensis* and indeterminable shell-fragments.
			(5)	Shales, black	0	4	*Pteria contorta,* common.
			(6)	'Beef,' often resting upon a hard limestone	0	1	*Pleurophorus elongatus, Chlamys valoniensis, Placunopsis alpina, Nuculana* cf. *titei* (Moore), *Actæonina fusiformis* (Moore), *A. oviformis* (Moore), *A. ovalis* (Moore),
			(7)	Shales, black	0	1	
		7.		Limestone, grey-black, somewhat shaly	0	7	
		8.	(1)	Shales, black, thinly laminated	3	6	
			(2)	Limestone, impure, shaly, full of shells	0	2	
			(3)	Shales, black, thinly laminated ...	3	6	

Division	Bed		[Blue Anchor Point.]	Thickness in feet	inches.	
Lower Rhætic (continued). Westbury Beds (continued).	9.		Limestone, very hard, crystalline, slightly pyritic	0	6	Fish-scales.
	?10 to 12.		Shales, black, laminated Foreshore Section near the First Gypsum-Workings. Shales, black	6	5	[Suggested approximate thickness.]
	13.		*Pleurophorus* Bed. The *Pleurophorus* Bed proper is a dark-grey, earthy fissile limestone crowded with *Pleurophorus*, and constitutes the lower portion of the bed. It is separated from the upper by a little shaly matter or 'beef,' while the upper portion of the bed is often replaced by 'beef' or surrounds lenticular masses of hard dark limestone	0	4	*Gervillia præcursor* Quenstedt, *Pleurophorus elongatus* (very common), *Isocyprina ewaldi* (Bornemann), *Chemnitzia* (two species), *Ch. granum* Dittmar, small coprolites, fragment of an ichthyodorulite of *Nemacanthus*.
	14.		Shales, black	1	1	No fossils seen.
	15.		The Bone-Bed. Upper layer a hard massive grit, with many fish-remains. It is separated from the lower bed by a distinct parting. This lower bed is a fine-grained, more regular crystalline rock, conspicuously ripple-marked	0	6	*Isocyprina ewaldi*, peculiar tracks as indentations *Gyrolepis alberti* Ag., *Acrodus minimus* Ag., *Ceratodus latissimus* Ag., *Hybodus minor* Ag.
	16.		Shales, black, laminated	3	2	
	17.	(1)	Limestone, hard, grey, micaceous and often somewhat siliceous: 0 to 5 inches	0	9	
		(2)	Shale, often containing a thin band (1 inch) of shelly limestone: 0 to 2 inches			
		(3)	Limestone, fissile, arenaceous: 0 to 2 inches			(3) *Isocyprina ewaldi*.
	18.		Shales, black	1	6	
	19.		Limestone, grey, in lenticular masses; baryto-celestine: 0 to 6 inches	0	3	
	20.		Shales, black, with a number of more or less prominent sandstone-layers at the base	0	6	
	21.	(1)	Limestone, rather prominent, very hard, irregular, often of septariform nature where the *Pteromya*-Limestone is wanting: 0 to 10 inches	0	8	
		(2)	Shale: 1 inch			
		(3)	Limestone (*Pteromya* Bed). Hard grey and dark-grey limestone: 1 to 3 inches			(3) *Pteromya crowcombeia* Moore, very common, *Isocyprina ewaldi*.
	22.		Shales, black: 10 to 14 inches	1	0	
	23.		Limestone-nodules, greyish-blue, hard, at considerable distances apart horizontally: 0 to 2 inches	0	1	*Protocardia* sp. indet.
	24.		Shales, black	1	2	*Pteria contorta*, *Isocyprina ewaldi*, *Pleurophorus elongatus*, *Natica oppeli* Moore, *Chemnitzia* sp. nov., and *Ch. granum*.
	25.		Limestone, hard, grey-blue, somewhat intermittent, nodular in places: 0 to 4 inches	0	2	
	26.	(1)	Shales, black, about	3	0	
		(2)	Limestone or greenish-grey impure sandstone, mixed with some black shale: sometimes absent, but usually about	0	6	Peculiar protuberances like the hardened infillings of tubular bodies.
		(3)	Shales, black	3	0	

[Blue Anchor Point.]

	No.		Description	Thickness in feet	inches.	
LOWER RHÆTIC (*continued*). Westbury Beds (*continued*).	27.		'The Clough.' Limestone, hard, grey-blue, nodular, with calcite in central cavities attached to the nether side of a thin black shelly limestone, which in its turn is separated by shaly matter from a 'bone-bed' limestone	0	4	*Acrodus minimus*, *Gyrolepis alberti*, *Hybodus minor*, saurian rib, *Nuculana titei* (Moore), in the uppermost layer.
	28.		Shales, black, laminated	1	3	
	29.	(1)	Sandstone, soft, light-grey, partly pyritic: a 'bone-bed'	0	4	Comminuted fish-remains.
		(2)	Shales, black	0	0½	
		(3)	Sandstone, thin layer of earthy	0	1	
	30.		Shales, blackish-green, marly, with pale greenish-grey nodules (here very conspicuous) near the base, and some thin gritty limestone-layers near the top	1	3	
	31.	(1)	Sandstone, in irregular masses	0	1	
		(2)	Shale, dark-green and black, marly.	0	1	
		(3)	Sandstone, whitish, in very irregular masses, spangles of white mica	0	5	
	32.	(1)	Shales, black, marly	0	3	
		(2)	Limestone, very pale-grey, rather crystalline	0	1½	*Pteria contorta*, *Isocyprina* sp., *Pleurophorus elongatus*.
		(3)	Shales, black	1	6	
	33.	(1)	Shelly bed, limestone in places	0	1	*Acrodus minimus*, *Gyrolepis alberti*, *Saurichthys acuminatus* Ag., *Hybodus minor*, *Sargodon tomicus* Plieninger, *Lepidotus(?)* teeth, *Pteria contorta*.
		(2)	Shale, black	0	3	
		(3)	Basal Bone-Bed, resting upon the Sully marlstone and containing derived lumps thereof	0	2	
				46	2½	

Blue Anchor Point (*pars*).

	No.	Description	Feet	Inches	
Sully Beds.	1.	Two massive beds of marlstone, greyish-green, but weathering yellow and parted by a thin layer of darker and less compact marl: estimated at	3	6	
	2.	Marl, laminated, yellowish-brown: estimated at	0	5	
	3.	Marls, greenish-grey, with indurated zones	2	0	
	4.	Marls, black, shaly, more indurated above	1	9	
	5.	Marlstone, weathering yellowish	0	8	
	6.	Marl, dark, shaly	0	3	
	7.	Marlstone, grey, weathering yellow	1	4	
	8.	Marl, soft, dark, shaly, with a 9-inch band of marlstone about the centre	1	8	
	9.	Marlstone, greyish	1	5	Fish-remains (scales and small coprolites).
	10.	Marl, soft	0	1	
			13	1	
KEUPER.	1.	Hard grey marl, with a dark zone at the base	1	6	
	2.	Marls, soft, black predominating in the lower half and yellow in the upper	2	10	
	3.	A series of layers of gypsum interstratified in very dark greenish-grey marls, with a particularly massive layer at the base. The gypsum is pink and white, fibrous, and occurs mainly in horizontal layers	7	0	

KEUPER (*continued*).

GREY AND TEA-GREEN MARLS (*continued*).

	[BLUE ANCHOR POINT (*pars*).]	*Thickness in feet*	*inches.*
4.	Pale, greenish-grey marl, less compact but containing more ramifying beds of gypsum than the bed below	4	0
5.	Pale, greenish-grey, more compact marl than 4, but with only occasional veins of gypsum	2	3
6.	Series of grey, gypsiferous marlstones, grey and green marls and marlstones: 8 to 10 feet..................................	9	0
7.	Dark greenish-grey marl	1	8
	Conspicuous layer of white fibrous gypsum	0	2
	Marl similar to (1)	4	0
8.	Greenish-grey and slightly yellow marlstones (three beds), separated by black shaly matter	2	7
9.	Black shaly marls, not very compact, alternating with greenish-grey marls and traversed by veins of gypsum......	6	4
10.	Three or four beds of greyish-green marlstone, with black marl separating them, and traversed like the beds above and below by thin veins of gypsum	4	0
11.	Marlstones, grey, separated from the bed below by marl, green in the lower portion, black in the upper (7 inches), passing up into less massive grey marlstones mixed with much more black marl containing pink gypsum, and lastly—at the top—into a black shaly deposit, in which marlstones are subordinate and there is more gypsum ...	9	0
12.	Two massive beds of greenish-grey marlstone and much pink gypsum. These are the two bands so conspicuous in Blue Anchor Point	2	6
13.	Grey nodular marlstones, with black shaly marl, much pink gypsum, and veins of white gypsum....................	4	2
14.	Marl, green, with some pink gypsum and a very regular layer of white fibrous gypsum. Below this are veins of pink gypsum obliquely arranged ...	8	9
15.	Seven layers of somewhat nodular greenish-grey marlstone interbanded with black shaly marl, which has running in it layers of gypsum mainly in a horizontal position, while the pink layers are in the main obliquely arranged. The topmost marlstone is more regular, conspicuous, and of a lighter colour ...	7	0
16.	Marlstone, hard, dirty, yellowish-grey, gypsiferous at the top	1	10
17.	Dark green marl, with a thin but conspicuous layer of white gypsum near the top	1	3
18.	Marl, blackish, with a green tinge and a faint red zone near the base. It is traversed by one very conspicuous layer of white fibrous gypsum and also by oblique and ramifying veins of pink. At the top is a noticeable zone of pink gypsum in green marl, overlain by blackish marl that fills up the irregularities in the hard layer of gypsum below	6	6

[Blue Anchor Point (*pars*).]

			Thickness in feet	inches.
KEUPER (*continued*).	19.	Marl, blackish	0	2
	20.	Marlstone, hard, greenish-grey	1	0
		Marl, greenish	0	4
		Pale pink gypsum	0	3
		Marlstone, hard, yellowish-green	1	0
	21.[1]	Greyish-green and dark marl	8	6
	22.	Marl, greenish	1	0
		Marlstone, grey	0	6
		Marl, greenish	1	3
	23.	Greenish-grey marl, with a black zone at the base	1	6
	24.	Greenish-grey marl with a red zone	2	0
	25.	Marlstone	0	5
	26.	Greenish marl and marlstone	1	0
	27.	Greenish and dark marls, with two red zones at the base	3	0
	28.	Massive greenish-yellow marlstone	2	3
	29.	Marlstone, greenish-grey	0	6
Red Marls.		Marls, red and variegated, faulted against the Lower Lias.		
		Total	111	0

Proceeding along the shore, and passing the Warren-Farm section and the point where the track from the lime-kilns descends to the shore—at about the place in the cliff which is above the arrow on the left-hand side of the scene depicted in fig. 1 (p. 13), the observer will find an interesting exposure.

Section in the Cliff near the Lime-Kilns, west of Watchet.

				Thickness in feet	inches.	
Cotham Beds (base).	4.	(1)	[Shales: removed by denudation.]			
		(2)	Limestone, cream-coloured and grey, with darker streaks and nodular in places: seen	0	9	Sun-cracks.
		(3)	Shales, marly, brown, passing down into	2	4	Very shelly.
Westbury Beds (top).	5 *a.*		Shales, black, brown, and grey			
	5 *b.*		*Cardium-cloacinum* Bed. Limestone intermittent	0	3	*Cardium cloacinum* Qu., *Pleurophorus elongatus* Moore, *Isocyprina* sp., *Myophoria emmerichi* Winkler, fish-scales, etc.
	6.		Shales, black: seen	6	0	

Bed 4 (2) is interesting, having sun-cracks in its component layers, and reminds one of the *Lycopodites* Beds at New Clifton, Bristol.

On this west side of Watchet there are no other sections that require attention.

Coast between Watchet and Combwich.—Sections in the foreshore immediately to the east of Watchet have been described by Prof. Boyd Dawkins, and those in the railway-cuttings at Doniford by J. H. Blake; but, so faulted are the beds, that their investigation is more interesting from the tectonic than from the stratigraphical point of view.

---

[1] The details of the beds from 21 downwards were obtained at the Warren-Farm section.

St. Audrie's Slip section.—The first section to notice east of Watchet is the fine one at St. Audrie's Slip. Its earliest describer was Robert Etheridge, who, in a paper read in 1871 (Proc. Cottesw. Nat. F. C. vol. vi, p. 40), spoke of it as the

> 'most complete section of the Rhætic Series in Somersetshire, if not in the West of England (except Penarth) . . . .'

The Rev. H. H. Winwood, writing in 1896, thought that this probably was so (Proc. Geol. Assoc. vol. xiv, p. 381); but at the present time (1905) the lower part of the Westbury Beds is obscured, and was so apparently in 1871: for Etheridge remarks that

> 'the measured section in full detail was constructed some years since, at a time when the Black Shales were in better order than at present, the sea having made extensive ravages and changes in its aspect.'

Etheridge made his measurements in company with Bristow, and the joint section was published officially by the Geological Survey in 1873 (Vert. Sects. Sheet 47, No. 6).

In the recently published (1908) Geological Survey Memoir on the 'Geology of the Quantock Hills, &c.' (p. 68), the official section is re-stated, but in an abbreviated form.

SECTION AT ST. AUDRIE'S SLIP, NEAR WATCHET.

				Thickness in feet	*inches.*	
LOWER LIAS.		*a.*	Limestone, rather earthy, brownish-grey, with blue-grey centre	0	4½	*Ostrea liassica* Strickland, *Volsella minima* (Sow.). '*Ostrea*-Bed' of Bristow & Etheridge: 'Bottom Lias' of Dunball.
		b.	Clay, brown and black, or limestone: 1 to 3 inches.	0	2	
		c.	Limestone, very pale grey-brown, traversed by extremely thin ramifying calcite-veins	0	3½	
			Shales, bluish-grey, passing down into	1	0	Paper-Shales.
				1	10 seen.	
UPPER RHÆTIC.	WATCHET BEDS.	1.	Shales, greyish, thinly laminated. Some of the layers have conjoined, and simulate hard beds. At the base (for an extent exceeding 5 inches) these shales are more earthy ...	4	2	*Grammatodon lycetti* (Moore), *Isocyprina (?)* sp.
		2.	Limestone, earthy, bluish-grey, somewhat nodular: maximum	0	5	Ill-preserved specimens of *Ostrea liassica* are common.
		3.	Shales, rather earthy, bluish-grey: 2 to 4 inches ...	0	3	*Ostrea liassica.*
				4	10	
	LANGPORT BEDS.	1.	Limestone, yellowish exterior, cream-coloured with bluish-grey patches inside, conchoidal fracture. Surface very irregular	0	5	*Volsella* of the *V.-minima*-group (Moore *non* Sow.); *Ostrea (?)* on the upper surface.
		2.	Shale, brownish, clayey ...	0	0½	

[St. Audrie's Slip.]

			Thickness in feet	*inches.*	
UPPER RHÆTIC (*continued*). Langport Beds (*continued*).	3.	Limestone, yellowish exterior, grey interior. The top is fairly even; but the lower portion is rubbly and shelly, containing nodular masses with pitted surfaces, and has a most uneven base-line	0	9	The upper bed has on its surface *Plagiostoma valoniense* (Defrance), *Dimyodon intusstriatus* (Emmerich). In the rubbly portion *Plagiostoma valoniense*, *Protocardia*, an echinoid-radiole, and ostracoda—the last, common.
	4.	Shale, bluish-grey, indurated and calcareous, especially at the base	0	11	
	5.	Limestone, grey, earthy, with a slight bluish tinge.	0	6	
	6.	Shale, bluish-grey, earthy.	0	3	
		Limestone, hard, blue-grey, very slightly pyritic. Often divides, and in places dies out. 1 to 4 inches	0	2½	Shells rare, but a few specimens of *Volsella* were noticed.
	7.	Limestone, hard, grey, conchoidal fracture, slightly pyritic in places. Calcite crystals. 0 to 3 inches	0	2	
	8. (1)	Shale, bluish-grey	0	0½	
	(2)	Limestone, similar to 7. Where 7 is developed 8 (2) is not, and *vice versâ*. 0 to 3 inches	0	2	
	(3)	Shale-parting	0	0½	
	9.	Limestone, bluish-grey with darker parallel streaks and conchoidal fracture	0	4	'Cotham Marble' of Bristow & Etheridge.
	10.	Shale-parting	0	0½	
	11.	Limestone, average	0	3½	
			4	2	
Cotham Beds.	1.	[Position of Cotham Marble, but not noticed by me at this locality.]			
	2.	Shales, greenish-grey, laminated, calcareous, with a few thin, greenish-grey, micaceous (white) sandstone-layers in the lower half	2	0	Ostracoda and a few fish-scales at the very top.
	3.	Limestone, massive bed, pale greenish-grey, bluish-grey inside, fissile, passing down into	1	4	Ripple-marked.
	4. (1)	Shales, greenish-grey, with thin sandstone-layers	1	8	
	(2)	Limestone, similar to 3	0	6	
	(3) *a.*	Shales, pale greenish-grey, with thin sandstone-layers	0	3	
	b.	Limestone, hard, greenish-grey, usually present here	0	1	*Protocardia (?)* and fish-remains in the layer at the base.
	c.	Sandstone, several hard layers of greenish-grey immediately underlying 4 (3) *b*, and mixed with a subordinate amount of shale (see p. 25)	1	10	The lowest hard band contains many shell-fragments, including *Cardium cloacinum* Qu.
			7	8	

[St. Audrie's Slip.]

	Bed			Thickness in feet	inches.	
LOWER RHÆTIC. WESTBURY BEDS.	5 *a*.	(1)	Shales, black; with layers of 'beef' in places, and impure limestone-beds	3	6	In the uppermost 3 or 4 inches *Pteria contorta* is abundant; but below the shales are more laminated, and contain few fossils except along certain lines.
		(2)	Limestone, dark grey, shaly, with 1- to 2-inch layer of 'beef' on the top or below: maximum	0	8	
		(3)	Shales, black: 21 to 25 inches	1	11	Along certain lines the following fossils are numerous: *Pteria contorta* (Portlock), *Isocyprina ewaldi* (Born.), *Chlamys valoniensis* (Defrance), large *Placunopsis alpina* (Winkler), *Nuculana* cf. *titei* (Moore).
	5 *b*.		*Cardium-cloacinum* Bed; blackish earthy limestone with a 1½-inch layer of 'beef' on the top, and in places very hard pale greyish limestone-nodules below	0	3	*Pteria contorta*, *Dimyodon intus-striatus*, *Chlamys valoniensis*, in the earthy limestone. In the nodules, *Protocardia rhætica* (Merian), *Pteria contorta*, *Chlamys valoniensis*, *Nuculana* cf. *titei*, *Actæonina fusiformis* (Moore), *A. ovalis* (Moore), *Natica oppeli* Moore, *Placunopsis alpina*, *Cardium cloacinum*, *Serpula (?)*.
	6.	(1)	Shales, black; crowded with fossils	0	3	*Chlamys valoniensis*, *Pteria contorta*, *Dimyodon intus-striatus*, *Placunopsis alpina*.
		(2)	'Beef,' resting upon dark shaly limestone, in which fossils are not numerous. Joined on to this is a still more shaly limestone, with a half-inch layer of 'beef' at the base	0	2½	
		(3)	Shales, black	0	0½	
	7.		Limestone, grey-black, massive, shaly in upper portion. Thin layer of 'beef' at the base, 4 to 10 inches ...	0	7	*Chlamys valoniensis*, *Pleurophorus elongatus* Moore, *Pteria contorta*, *Placunopsis alpina*, *Volsella* sp., and a few fish-scales.
	8.		Shales, black, laminated, with layers of 'beef' at 4, 29, and 44 inches from the base. Many gypseous aggregations in the shale between the laminæ. The lowest 4 inches non-laminated. Hard, greyish-black, shelly limestone at the base (1 inch therefrom)	6	2	Shell-débris immediately above the third 'beef'-layer from the base, and again at the top.
	9.		Limestone, hard, grey, with shells inside but too firmly encased for extraction......	0	8	On the top *Pteria contorta*, *Myophoria emmerichi* Winkler, rare; Etheridge & Bristow record, in addition, *Anatina suessi* Oppel, and *Plagiostoma valoniense*.
	10.		Shales, hard, thinly laminated: about	2	6	
	11.		'Beef,' resting upon a thin grey earthy limestone with shell-débris	0	2	
	12.		Shales	3	6	*Gervillia præcursor* Qu., *Protocardia rhætica*, *Pteria contorta*.
	13.		Limestone, very hard, crystalline, pinkish, slightly pyritic, in two beds. The upper bed is 2 inches thick, *Pleurophorus* Bed; the lower is 5 inches thick, with a layer of 'beef' and shale intervening	0	8	*Isocyprina ewaldi*, *Pleurophorus elongatus* (very common), *Chemnitzia (?) henrici* Martin (very common), *Nuculana* cf. *titei*.

			[St. Audrie's Slip.]	*Thickness in feet*	*inches.*	
LOWER RHÆTIC (*continued*).	Westbury Beds (*continued*).	14.	Shales, black, laminated: 15 to 21 inches	1	6	
		15.	The Bone-Bed. Five layers of a dull grey siliceous rock with rolled pieces of limestone, and at the base a layer free from pebbles	0	5	*Acrodus minimus* Ag., *Gyrolepis alberti* Ag., fragments of bone and coprolites, shell-débris (*Isocyprina?*), and small quartz-pebbles.
		16.	Shales, black	1	3	
			Sandstone layers, thin, greenish-yellow, mixed with black shale	0	3	
			Shales, black	1	6	
		17.	Limestone, hard, grey. Selenite and baryto-celestine, and fibrous calcite ('beef') in joints	0	5	Shelly at the base, where it contains *Isocyprina ewaldi*, *Volsella minima* (Moore *non* Sow.), and *Pleurophorus elongatus*. *Protocardia rhætica* (*teste* Etheridge).
		18 to 22.	Shales, black. From Bed 17 to the marls, according to Etheridge, is 6½ feet less 1 foot 9 inches	[4	9]	
		23.	Limestone-nodules, hard, blackish: 0 to 2 inches	0	1	
		24.	Shales, black and green-speckled	1	6	
		25.	Black earthy shale, with lumps of pale-grey marl. Basal Bone-Bed	0	3	
				33	0	
	Sully Beds.[1]		Hard, pale-grey, earthy marlstone	0	4	Fish-scales.
			Greenish-grey marl	0	4	
			Marl, hard, pale	0	6	
			Marl, greenish grey	0	10	
			Marl, hard, pale	0	2	
			Shale, pale-grey, marly, with thin lines of hard marl in the middle	1	0	
			Marl, hard, pale-grey, with lines of softer marl	1	3	
			Marl, dark grey, tough, with conchoidal fracture and thin hard sandy lines	0	7	Annelid-burrows and *Gervillia præcursor*.
				5	0+ ?	

Beds *a*, *b*, & *c* constitute the '*Ostrea*-Bed' of Bristow & Etheridge, and correspond to the 'Bottom Lias' of Dunball.

The authors of the official record, of the notes in the Geological Survey Memoir, and myself, all differ with regard to the point where the line between the Rhætic and the Lias should be drawn; but I think that the horizon at which I have placed it is in harmony with the allocation that I have made at other localities.

The component layers of the Langport Beds agree very closely with their equivalents at Blue Anchor Point and Lavernock, and do not require anything to be said about them—beyond drawing attention to the fact that the lower layer of the compound bed identified with the Sun-Bed is very rubbly at the base, and contains well-rolled

---

[1] The details of the Sully Beds are derived from Bristow & Etheridge's account.

pieces of close-grained compact limestone, thereby indicating a slight non-sequence. Bristow & Etheridge noticed this rubbly condition of the bottom part of the Sun-Bed in their record.

I have indicated the place where I should expect to find the Cotham Marble if a longer search had been possible. The horizon pointed out is somewhat lower than that occupied by the stratum suggested by the Geological Survey officers as its probable equivalent. As showing that the suggestion, that a continuous stratum such as they indicate is the equivalent of the Cotham Marble, is improbable, it may be remarked that in Mid and West Somerset the equivalent of the Cotham Marble is generally an intermittent layer of nodules—not a continuous limestone-bed.

A very interesting feature about this St. Audrie's-Slip section is the peculiar arrangement of the deposits in the neighbourhood of the junction of the Langport and Cotham Beds. At the base of the former division is Bed 4 (3) *b*: it is remarkably persistent, and therefore constitutes a good datum-level. But, while in one place it rests directly upon the *Pteria-contorta* Shales, in another it is separated therefrom by a greenish marl 22 inches thick [Bed 4 (3) *c*].

At this horizon, at Charlton-Mackrell (p. 42) and Sparkford-Hill (p. 48) railway-cuttings, occur those remarkable boulder-like masses of limestone which themselves are indicative of disturbed conditions of sedimentation. Here at St. Audrie's Slip is evidence pointing in the same direction, and these facts considered together afford some explanation of the circumstance that the *Pteria-contorta* Shales, with their well-known blackness, give place comparatively so suddenly to the pale marls and limestones of the Cotham Beds, which had obviously a very different history.

Bed 5 *b* is again easily found—its hard nodules being covered with well-preserved fossils. Species of *Actæonina* and *Natica oppeli* Moore are particularly abundant.

The *Pleurophorus* Bed is richly fossiliferous when found; but the same cannot be said for the Bone-Bed. This bed is somewhat disappointing, and totally unlike its equivalent stratum farther west near Blue Anchor. It is a conglomeratic rock, consisting of subangular pieces of grey-blue limestone embedded in a greenish, siliceous, and earthy brown matrix—the greenish siliceous and micaceous matter also forming an almost pure layer at the base.

The Westbury Beds below stratum 17, with the exception of the basal bone-bed, were not well-exposed when I visited the locality, and so I have had to rely upon Bristow & Etheridge's figures for the thicknesses of the deposits intervening between Bed 17 and the Sully Beds. The basal bone-bed is very similar to that which occupies an equivalent position all along the coast to the west of Watchet and between that locality and Blue Anchor; but vertebrate-remains are not quite so numerous here.

A noticeable feature about the Keuper is the scarcity (if not absence) of layers of gypsum, which are so numerous at Blue-Anchor Point. Between the base of the *Pteria-contorta* Shales and the top of the red marls (Keuper) intervenes—according to Bristow

& Etheridge—no less than 115 feet of deposit, of which I surmise a thickness of about 14 feet belongs to the Sully Beds.

Lilstock section.—The last section to notice in the Watchet area is that on the coast at Lilstock (Little Stoke, auctt.). From the stratigraphical standpoint it is by far the most satisfactory, for the beds are undisturbed by faulting, landslides, or accumulated talus. The *Pteria-contorta* Shales are particularly well displayed and easily accessible.

Lilstock has been mentioned by Etheridge as a locality where 'the Rhætic beds are developed with great distinctness,' and he has also given a diagrammatic section to show the disposition of the beds in the cliffs around the little bay.[1] But, except for this brief notice, the section has been hitherto ignored—probably because of the difficulty of reaching it. Williton, near Watchet, is the nearest railway-station, and that is about 7 miles distant.

Having arrived at the cottage by the old and partly destroyed landing-stage, the observer will notice that the first portion of the cliff (immediately to the east of the buildings) is just capped by the *Pteria-contorta* Shales; while the marlstones of the Sully Beds, being harder than the overlying shales, have resisted denudation better and project, forming a prominent feature. Eastwards the beds gradually descend, and continuing in that direction the observer will find a place where the greatest stretch of talus occurs, and where therefore it is easiest to reach the deposits at the junction of the Cotham and the Langport Beds. It is here that the relationship of the equivalent of the Cotham Marble to the superincumbent Langport Beds can best be studied.

Below, but a little farther east, and standing out conspicuously, are the marlstones of the Sully Beds; and yet a short space beyond, is the place where the complete sequence from them to the Lower Lias can be quite satisfactorily studied.

Capping this portion of the cliff is the massive Lower Liassic limestone, corresponding to the 'Bottom Lias' of Dunball. Its conspicuousness affords additional guidance to the position of the section under consideration.

From this point around the little bay the rocks are extraordinarily faulted; but, as the prevalent inclination is to the south, or somewhat west of south, it follows that by proceeding along the eastern side of the bay the geologist will encounter lower and yet lower deposits, until just before the Keuper and Rhætic deposits are brought into juxtaposition with the Lower Lias by means of another fault, he obtains a glimpse of the true Tea-green Marls alongside the fault-plane close down to beach-level.

Returning to the main section, I will deal first with the Sully Beds. They are easy to examine, well-developed, and more than usually fossiliferous. Organic remains have been found as far down as 7 feet 9 inches below the base of the *Pteria-contorta* Shales, so it is

---

[1] Proc. Cotteswold Nat. F. C. vol. vi (1871–77) p. 39 & fig. 1.

there that must be drawn for the present the line between Rhætic and Keuper. Further investigation may lower the line; but this reduction in thickness prepares us for the fact, that in the railway-cutting at Dunball the Sully Beds are probably represented by a bed only 10 inches thick.

The uppermost foot or so of Sully Beds at Lilstock is crowded with specimens of *Pteria contorta*, and the topmost layer is identical lithically and palæontologically with the layer at the top of the Sully Beds at St. Mary's Well Bay, Sully. It is impossible to distinguish between hand-specimens from the two localities.

The Bone-Bed is a very hard, grey, siliceous sandstone, not unlike the foreshore Bone-Bed at Blue Anchor; but the sand-grains are smaller, and the vertebrate-remains more comminuted. Obscure moulds of *Isocyprina* occur, with the tests replaced by iron-pyrites; and associated with them are small coprolites, the usual fish-remains, and a few small quartz-pebbles.

In this country the deposits between the main Bone-Bed (15) and the Sully Beds, or, if they are absent, the Keuper, are best described as the 'infra Bone-Bed deposit,' for an attempt at more minute correlation of their component beds is not generally attended with very satisfactory results—the strata varying so much from place to place. However, in so far as Lilstock is concerned, I have made some suggestions as to their individual correlation; but it must be remembered that these are only suggestions, nothing more.

Bed 9 is very conspicuous, and I do not think that there is much doubt that it is on the same stratigraphical horizon as the similarly-numbered beds in the Dunball and Charlton-Mackrell railway-cuttings. Horizon 5 *b*—the *Cardium-cloacinum* Bed—is not distinctive: at least I did not discover its familiar, fossiliferous little nodules.

The component deposits of the Cotham Beds, again, agree very fairly with their equivalents elsewhere, and there are no signs that a disturbance affected the ordinary process of their deposition.

The break occurs higher up indeed—at the top of the Cotham Beds. Here is very instructive and quite unmistakable evidence that, after the formation of the Cotham-Marble equivalent, and before the time of deposit of Bed 10 of the Langport Beds, there was a disturbance of the sea-floor resulting in a remarkable bed consisting of limestone-masses of all sizes up to 18 inches in vertical length, to which pieces of Cotham-Marble equivalent are frequently adherent. In other parts of the section the Cotham-Marble equivalent is joined on to the hard basal stratum of the Langport Beds.

It should be noticed also that the lower stratum of the Sun-Bed here, as at St. Audrie's Slip, is somewhat conglomeratic.

The Watchet Beds are of the same thickness as at St. Audrie's Slip, but are usually separated by a limestone-bed from the succeeding Paper-Shales, which are in turn capped with the massive 'Bottom-Lias' limestone.

SECTION AT LILSTOCK.

			Thickness in feet	*inches.*	
LOWER LIAS.		Limestone, hard, blue-centred; very conspicuous	1	1	*Ostrea liassica* Strickland.
		Clay, brown, shaly	0	2	
		Limestone: 2 to 7 inches	0	5	='the Clogs' at Dunball.
		Shale	0	1½	
		Limestone, shaly	0	1½	
		Shale and clay, brown and grey	1	3	*Volsella minima* (Sow.).
		Limestone, blue-centred	0	5	='Lias Paviours' of Dunball.
		Shale and clay, brown	0	3	
		Limestone, very massive, dark grey	1	2	='Bottom Lias' of Dunball.
		Shales, hard, brown, passing down into	0	8	Paper-Shales.
		Limestone, rather shaly in places, but usually a well-marked bed	0	4	
			6	0	seen.
UPPER RHÆTIC. Watchet Beds.		Shales, yellowish-brown and grey, not so thinly laminated	3	0	*Volsella* sp. (crushed).
	1. 2.	Limestone, often not a very conspicuous bed, as it passes into a yellowish rubbly deposit, but is always present in one form or the other	0	3	
		Shales, papery, hard, thinly laminated, brown and grey-speckled	1	1	
	3.	Shales, earthy, yellowish, with a thin blue zone at the centre and a few gritty seams	0	6	*Ostrea liassica*, common in the blue zone.
			4	10	
Langport Beds.	1.	Sun-Bed. Limestone, brownish-grey, yellow exterior	0	5	
	2.	Shale-parting, brownish yellow. Nodular masses of a grey-brown limestone are often present here, making, with the bands above and below, three beds with marl-partings. Often the top limestone becomes nodular, and combines with the middle layer: 0 to 4 inches	0	2	Very variable beds: 1 & 3 should be found first, and then the intervening portion can be made out. *Ostrea liassica*.
	3.	Limestone, bluish-grey, very hard, yellowish exterior; contains pebbles of a hard compact limestone as at Pinhay Bay, near Lyme Regis	0	4	*Dimyodon intus-striatus* (Emmerich), *Volsella minima* (Moore *non* Sow.), *Plagiostoma valoniense* (Defrance).
	4.	Marl and hard brownish blue-centred rubbly limestone: 8 inches	1	8	'Rubbly Beds.' Fossils of Bed 3; and, in addition, *Protocardia rhætica* (Merian).
	5 to 8.	Very pale yellowish-green and rather sandy-looking beds; stratified: 1 foot			
	9.	Limestone, hard, dark blue, shelly, forming a conspicuous bed and a useful datum-level; ferruginous: 3 to 7 inches	0	5	
	10.	Shale, yellowish	0	2	
	11.	Limestone in nodular masses, brownish-grey, weathering pale yellow. (See p. 27.) 0 to 18 inches	0	9	
			3	11	

[Lilstock.]

					Thickness in feet	*inches.*	
UPPER RHÆTIC (*continued*).	Cotham Beds.	1.		Cotham-Marble equivalent. A splintery, brownish-grey limestone: 0 to 6 inches	0	3	
		2.		Marls, non-laminated above, more so below. In places, at 18 inches below the Cotham Marble, is a hard, grey, sandy fine-grained limestone, and above it occur several thin brown layers. The topmost portion of all is conspicuously streaked brownish-yellow ...	3	8	
		3.		Limestone, grey, fissile and rather sandy, not always conspicuous, but in places harder and non-fissile	0	4	Fish-scales (fragments).
		4.	(1) (2)	Marls, bluish-grey, with a few not very conspicuous sandstone layers. More indurated in a zone at the top	1	2	
			(3)	Limestone, grey and yellow, sandy, with a little yellowish marly matter intervening	0	6	
					5	11	
LOWER RHÆTIC.	Westbury Beds.	5 *a*	(1)	Shales, black, with gypseous aggregations. At the top (for 2 or 3 inches) these shales are more marly	3	0	*Pteria contorta* (Portlock).
			(2)	Limestone, grey, which (together with a large amount of 'beef') makes up a hard zone	0	4	*Chlamys valoniensis* (Defrance).
			(3)	Shales, black, laminated. At the top (2 inches therefrom) are two hard-looking layers; but these, on closer inspection, are found to be bound together by selenite ...	2	6	*Protocardia rhætica.*
		5 *b* 6 7.		Limestone, blackish-grey, earthy, in three beds with shale-partings; sometimes in two when the shale-parting is thicker. On the top is a fairly regular layer of 'beef'	1	2	*Chlamys valoniensis*, *Pteria contorta* abundant in the shale-layers; *Gyrolepis alberti* Ag.
		8.		Shales, black, laminated, with two layers of 'beef' (conjoined) 40 inches from the base ... about	6	0	Usual Rhætic fossils.
		9.		Limestone, pale grey, usually hard and often nodular in appearance; 'beef' on the upper surface	0	10	
		10.		Shales, black	6	0	
		11.		Sandstone, grey, calcareous	0	0½	
		12.		Shales, black	0	4	
		13.		Limestone, dark grey, although conspicuous in some places it thins out in others to a thin brown soft seam, barely an inch thick: 1 to 5 inches	0	3	*Gyrolepis alberti.*
		14.		Shales, black, laminated	1	6	*Gyrolepis alberti*, *Hybodus minor* Ag., coprolites, small quartz-pebbles, and *Isocyprina*-casts.
		15.		Bone-Bed. Sandstone, very hard, grey, slightly pyritic, and micaceous at the base, becoming more of a limestone above	0	6	
		16.		Shales, black, thinly laminated, becoming greenish-speckled: 26 to 32 inches	2	5	

(Lilstock.)					Thickness in feet	inches.	
LOWER RHÆTIC (*continued*).	Westbury Beds (*continued*).	17.	(1)	Shale, indurated, selenitic. 'Bone-Bed'	0	1	Coprolites numerous, *Hybodus minor*, *Gyrolepis alberti* (scales and ? teeth).
			(2)	Shales, black, with gritty layers	0	3	
			(3)	Sandstone-layers, thin, grey, mixed with shale and much selenite	0	2	
		18 to 22.		Shales, black, thinly laminated, with a number of thin gritty seams—especially at the base	0	6	
				Limestone, grey, shaly, but hard and dark grey in places: 4 to 6 inches	0	5	*Isocyprina ewaldi* (Bornemann).
				Shales, black, laminated, green-speckled, with much selenite	0	9	
				Limestone, hard, greyish, in lenticular masses, somewhat nodular: maximum	0	5	
				Shales, black, very selenitic; 2½ to 3 feet	2	9	*Pteria contorta.*
		23.		Limestone, very hard, with black nodules	0	2	
		24.	(1)	Shales, black, becoming green along the laminæ	1	4	
			(2)	Thin gritty layer	0	0½	
			(3)	Shales, black	0	3	
					32	0	
	Sully Beds.	1.		Impure, bluish-grey, shelly, sandy limestone, micaceous in layers with shale-partings. The top layer is the most massive, the others being thinner and having very thin shale-partings. A little more to the east brownish-green, very shelly, impure limestones predominate	0	10½	*Pteria contorta* very common, *Volsella* sp. indet. and much shell-débris, *Gyrolepis alberti*, *Sargodon tomicus* Plieninger, *Lepidotus ?* (teeth), small Plesiosaurian tooth, quartz-pebbles.
		2.		Shale, black and brown	0	1½	*Pteria contorta* common.
		3.		Marlstone, greyish, shelly. The tests of the shells having been (in most cases) dissolved, a cavernous appearance is imparted to the bed	1	3	Fish-scales (fragments).
		4.		Marl, greenish-yellow and dark, hard in places at the top: maximum	1	1	
		5.		Marlstone, dark, greyish, with a tinge of green. The lower portion divides up into four rather regular bands	2	10	*Pteria, Protocardia (?)*, fish-scales.
		6.		Marl, greenish-yellow and dark, more rubbly	0	4	
		7.		Marlstone, greenish-yellow and black at the base. Usually divides into two main beds, with a thinner layer—the darker portion—at the base	1	3	Shell-débris, fish-scales.
					7	9	
KEUPER.				Marl, dark yellowish-green and blackish.			

(2) Mid Somerset.

(A) The Polden-Hills Area.

(i) Introduction.—The name Polden Hills is popularly applied to the noticeable ridge which presents a steep face south-westwards, but a gentle dip-slope north-eastwards, and, starting near Dunball, about 2 miles north of Bridgwater, runs in a south-easterly direction certainly as far as the Butleigh Monument. But, beyond that, it is doubtful whether popular opinion would permit of its extension. Considerable research and abundant enquiry have not forwarded matters: so—in accordance with the precedent set in the delimitation of the Cotteswold Hills—I may suggest that a definite contour-line be taken, and in the present case the 100-foot contour-line would answer the purpose best. The higher ground thus contained extends from Dunball to the neighbourhood of Charlton Adam, and is excellently shown on Bartholomew's 'Half-inch-to-a-Mile' map of England & Wales—Dorset (Sheet 34).

At Dunball at one end of the area, and near Charlton Mackrell at the other, magnificent sections have been displayed in railway-cuttings. The section at the former locality is still open, for its steep sides afford but little roothold for vegetation; but the section at the latter locality, with its sloping sides, is—despite its recent construction—almost wholly obscured. In the intervening district, as at Windmill Hill, Butleigh, higher strata (belonging to the Lower Lias) are well exposed.

The stratigraphy of the Rhætic in this area presents several points of difficulty, which additional detailed local work, aided, perhaps, by purposely-made excavations, can alone thoroughly elucidate. The main difficulty is encountered in connexion with the Langport Beds. At Dunball they are only 4 feet 3 inches thick; but at Charlton Mackrell, 20 feet 8 inches. There is not sufficient evidence available to show in precisely what manner this thickening has taken place: whether it is due simply to overlap on the part of the higher beds over the lower from east to west, or to some more complex cause.

In the Dunball-Ashcott portion of the Polden Hills, it would appear that the Langport Beds do not differ widely from their equivalents in the railway-cutting at Dunball. That is, they are thin, and the bottom massive limestones of the Langport Beds, or the 'Sizes' as they are locally called, cannot be definitely recognized. All the limestone-beds present appear to belong to the upper portion of the Langport Beds: in other words, the 'Sizes' may be wanting, or very poorly represented, in this Dunball-Ashcott district. Their absence or poor development may be due to the fact that this portion of the Polden Hills during the time of deposition of these beds was rendered unstable, owing to movements along an old anticlinal axis, which is now traceable at Blue Anchor Point, enters the Polden Hills near Knowle Hall (to the west of Bawdrip), is seen in the railway-cutting near Cossington, and

emerges again near Greinton, to be re-discovered at Camel and Sparkford Hills, which are probably part of its northern limb. If this axis is traced on a geological map, the suggestion presents itself that it is connected with the series of folds of which the Mendip Hills is one, such an equidistance therefrom does it preserve.

In this area the sections that should be visited are those in the railway-cuttings at Dunball and Cossington and in the quarries at Catcott, Windmill Hill, Butleigh, and Butleigh Hill. The following table shows the thicknesses of the several subdivisions at the two ends of the area—at Dunball and Charlton Mackrell.

TABLE III, ILLUSTRATING THE THICKNESSES OF THE SUBDIVISIONS OF THE RHÆTIC SERIES IN THE POLDEN HILLS.

			Approximate thicknesses in			
			ft.	*ins. at Dunball*	*and in ft. ins. at Charlton.*	
RHÆTIC.	UPPER.	? I. Watchet Beds	3	10	absent.	
		II. Langport Beds	4	3	20	8
		III. Cotham Beds	4	5	4	9
	LOWER.	IV. Westbury Beds	32	2	22	4
		? V. Sully Beds	0	10	absent.	

(ii) Stratigraphical details.—The deep railway-cutting at Dunball, the 'Puriton Section' of Bristow & Etheridge,[1] admirably displays the sequence from the Grey and Tea-green Marls to the Lias.

The Grey and Tea-green Marls are exposed on the west side of the cutting, at the commencement of the wall. Black shales are seen above, up to a prominent limestone-band—Bed 9. This bed is more accessible on the other (eastern) side of the cutting, where indeed there is a continuous sequence up to the rubbly limestones of the Langport Beds. Half-way towards the first bridge is seen the Sun-Bed, succeeded by the presumed equivalents of the Watchet Beds, which are in turn followed by the Paper-Shales; while beyond—on the same side of the cutting—come Liassic strata. The last, however, are better exposed on the western side.

The only published record of the Dunball section which contains original information is by Bristow & Etheridge, and from it the present record differs in but a few minor matters of fact. An abbreviated edition of Bristow & Etheridge's record is given in the recently-issued Geological Survey Memoir on 'The Geology of the Quantock Hills, &c.' (1908, pp. 70–71), where it is stated that Messrs. J. H. Blake, W. A. E. Ussher, & H. B. Woodward remeasured the section and apparently discovered no discrepancies.[2] They make no advance, however, in the matter of subdividing the Rhætic, not separating the greenish-grey marly beds below the Cotham Marble from the 'White Lias.'

The massive 'Bottom Lias' is at once noticeable. No limestone is recorded in the official section as parting the Paper-Shales from the presumed Watchet Beds. Probably it was absent from the

---

[1] Vertical Sections, Sheet 46, No. 1, Geol. Surv. 1873.

[2] See also 'Jurassic Rocks of Britain—The Lias of England & Wales Mem. Geol. Surv. vol. iii (1893) pp. 81–82.

place at which Bristow & Etheridge measured the section, or it may be that the shales were not sufficiently calcareous or indurated there to assume the aspect of a limestone-band. These geologists apparently recognized the equivalent of the Cotham Marble, but recorded only a few inches of shale between it and the next underlying limestone, instead of somewhere about 2 feet 2 inches. True, this shale varies somewhat in thickness. This is the main difference, as regards stratigraphical details, between our records; the other differences are so trivial that a prolonged comparison is unnecessary.

Section in the Railway-Cutting at Dunball, near Puriton.

			Thickness in feet	*inches.*	
LOWER LIAS.		Shales, hard, dark-grey, occasionally hardened into stone. ('Lias Paviours')	—		*Volsella minima* (Sow.).
		'Bottom-Lias.' Limestone, massive, evenly-bedded, bluish-grey, argillaceous	1	1	*Pleuromya crowcombeia* auctt.
		Paper-shales, hard, pale grey and brown: 22 to 26 inches	1	10	Paper-Shales; locally termed the 'Burning Scale.'
		Limestone, dark grey, rather earthy, frequently passing into shale. Usually, however, it is a noticeable bed	0	4	
			3	3	seen.
UPPER RHÆTIC. ? WATCHET BEDS.		Shales, grey, calcareous, more fissile here than usual: 3 feet 6 inches to 4 feet 2 inches	3	10	Locally the 'Cement' and 'Black Scale.'
			3	10	
LANGPORT BEDS.	1.	Sun-Bed, Jew, or Dew Stone. Limestone, very massive, greyish-brown, conchoidal fracture, with frequently a hard marly limestone 3 inches thick, called the 'Slippery Bed,' separating off from the top: 10 to 14 inches	0	11	
	2.	Shale-parting, greyish-green, marly.	0	0½	
	3.	Limestone, massive, with a conchoidal fracture, bluish-grey hearted: 8 to 10 inches	0	9	
	4.	Marl and very pale grey rubbly limestones. Sometimes the limestones are more prominent, particularly one near the top	0	6	
	5.	Limestone, dirty grey, rather earthy and irregular, with a hard cap: 2½ to 5½ inches	0	4	*Volsella minima* (Moore *non* Sow.).
	6.	Marl, pale grey, and thin rubbly limestones: 2½ to 4½ inches	0	4	
	7.	Limestone, bluish-grey hearted, yellowish exterior, soon breaks up	0	7	*Pleuromya crowcombeia* auctt., common in the lower portion; *Plicatula hettangiensis* Terquem.
	8.	Shales, pale grey, marly	0	3	[Often indurated at the Cement Works.]
	9.	Limestone, pale grey, rather argillaceous	0	3	These beds are frequently conjoined to form one stratum, 8 inches thick.
	10.	Shales, grey, often indurated, or absent altogether	0	2	
	11.	Limestone, hard, dark grey	0	1½	[1 to 3 inches.]
			4	3	

				[DUNBALL.]	*Thickness in feet*	*inches.*	
UPPER RHÆTIC (*continued*).				Shales, dark green, clayey...........	0	2	
	COTHAM BEDS.	1.		Cotham-Marble equivalent. Limestone in intermittent lenticular masses: 0 to 2 inches......	0	2	
		2.		Shales, calcareous, pale greyish-green, weathering white	2	2	[2 feet 4 inches at the Cement Works.]
		3.		Limestone, hard, greenish-grey, crystalline: 1 to 2 inches	0	2	[9 inches, and in three beds with shale-partings.]
		4.	(1)	Shales, greenish-grey, thickly laminated, calcareous: 7 to 9 inches...	0	7	[1 foot.]
			(2)	Limestone, hard, greenish-grey, passing into a fissile limestone with quartz-grains in the top layer: 6 to 10 inches	0	8	*Pleurophorus angulatus* Moore (*teste* Bristow & Etheridge). [4 to 10 inches.]
			(3)	Shales, black and brown, ferruginous .... about	0	6	[4 to 6 inches.]
							4 5
	WESTBURY BEDS.	5 *a*.	(1)	Shales, black	3	0	*Pteria contorta* (Portlock), *Isocyprina ewaldi* (Bornemann).
			(2)	Limestone, earthy, very ferruginous, with 'beef' and selenite	0	1	Fish-scales, shell-débris, *Chlamys valoniensis* (Defrance), *Protocardia rhætica* (Merian).
			(3)	Shales, black: 22 to 26 inches	2	0	
		5 *b*.		Limestone, hard, grey, irregular, slightly pyritic, with some admixture of shale: 1- to 2-inch layer of 'beef' on the top. Limestone, 4 to 8 inches	0	6	
		6.		Shales, black, weathering brown, selenitic: 12 to 14 inches	1	0	
		7.		Limestone, grey, very earthy, shelly, slightly pyritic, with a $\frac{3}{4}$-inch layer of 'beef' below: 2 to 4 inches	0	3	*Chlamys valoniensis*, etc.
		8.	(1)	Shales, black, laminated	2	4	
			(2)	Shales, indurated, very selenitic, simulating a hard band	0	2	
			(3)	Shales, black, thinly laminated, selenitic	1	8	
		9.		Limestone, massive, greyish-brown, somewhat nodular (of septarian formation), in places siliceous, traversed by ramifying fissures filled with calcite. This bed much resembles the Bone-Bed at St. Mary's Well Bay, Sully. The topmost 2 inches comprise indurated earthy and selenitic shale with impure limestone: 9 to 11 inches	0	10	The 'Flinty Bed' of Moore's Hatch-Beauchamp section.
LOWER RHÆTIC.		10.		Shales, black, thinly laminated ...	2	6	'*Pullastra* and *Axinus elongatus*' (*teste* Bristow & Etheridge).
		11.		Limestone, grey and black, earthy; much selenite and 'beef' on the under side. Passes into a very fossiliferous bone-bed	0	4	*Acrodus minimus* Ag., *Gyrolepis alberti* Ag., *Saurichthys acuminatus* Ag., *Hybodus minor* Ag., *Lepidotus?* (teeth), saurian ribs, coprolites.
		12.		Shales, black, prominently laminated, but not quite so much at the base. Very selenitic at the top	3	11	*Pteria contorta*, *Protocardia rhætica*.
		13.		Thin sandstone-layers, mixed with a preponderant amount of shale...	0	3	Fish-scales.
		14.		Shales, black, selenitic (in minute crystals)	1	8	

[DUNBALL.]

				Thickness in feet	inches.	
LOWER RHÆTIC (*continued*).	WESTBURY BEDS (*continued*).	15.	Thin sandstone-layers, grey, micaceous	0	3	Fish-scales. [1 to 3 inches.]
		16. (1)	Shales, black, thinly laminated	0	6	
		(2)	Shale, extremely selenitic, ferruginous, simulating a hard band	0	3	
		(3)	Shales, black, thinly laminated, gypseous aggregations	1	1	
		17. (1)	Limestone, dark grey, impure, arenaceous: 2 to 4 inches	0	3	
		(2)	Shale and thin sandstone-layers	0	1½	
		(3)	Limestone, hard, dark grey, arenaceous, 'with argillaceous concretions of pyrites in lower part' (Etheridge)	0	4	
		18 to 22.	Shales, black, laminated, with several thin, grey, fine-grained, micaceous sandstone-layers near the top. Selenite	4	4	*Pteria contorta, Protocardia rhætica.*
		23.	Sandstone, pale grey, non-calcareous, dense, fine-grained	0	0½	
		24.	Shales, black, laminated...... about	3	6	
		25.	Sandstone-layers, greenish-brown, micaceous, ferruginous, earthy, mixed with a preponderant amount of shale	1	0	
				32	**2**	
	? SULLY BEDS.		Dull yellowish-green earthy sandstone, slightly ferruginous	0	10	*Pteria contorta* (*teste* Etheridge).
				0	10	

? Non-sequence.

KEUPER.	GREY AND TEA-GREEN MARLS.	Marl, sandy, greenish-yellow	0	4	
		Marl, hard, greyish-yellow	0	8	
		Marl, less compact, darker yellow	0	2	
		Marl, yellowish-green, argillaceous, rubbly	1	3	
		Marls, dirty yellow, dark green, and black	2	4	
		Hard marl	0	7	
		Marls, dirty yellow, indurated in places	—		

Comparing this section with that already described at Lilstock, we shall first of all notice that the Sully Beds have become greatly reduced in thickness, and that at Dunball a 10-inch bed below the Black Shales is tentatively regarded as representing their uppermost portion. The thickness of the Westbury Beds at both places is about the same. Bed 9 is an easily found limestone, and at Charlton Mackrell was noted at about 15 feet above the base of the Black Shales.

At Dunball the principal bone-bed appears to occur at a higher horizon than usual, being the bed numbered 9; while the bed that is presumably on the horizon of the main Bone-Bed (that is, 15) contains but few vertebrate-remains. The Cotham Beds at Dunball and Lilstock agree very well, and so do the Langport Beds; but the Watchet Beds are not typically developed, and some care has to be exercised in separating them from the Paper-Shales when the dividing limestone is not distinctively developed.

Close to Dunball Station are the Cement & Lime Works. As

the deposits that are principally sought for in the workings are the *Planorbis* Beds, which lie towards the foot of the northern slope of the hill, a number of deep cuttings and tunnels had to be made, in order to allow of the passage of the trolleys from the workings to the kilns. The steep portion of the hill is thus literally sliced through, and a magnificent series of sections made available.

As might be expected, the differences between the beds exposed in these sections and those seen in the railway-cutting are trivial; but I have noted the more important of them in the railway-cutting section, giving the information in square brackets.

North of Bawdrip the rocks are affected by two approximately west-and-east faults, but their prevalent southerly dip is obvious, and is still more so in the fine railway-cutting on the way to Cossington Station, at which place the Black Shales of the Lilstock Beds reappear, forming the central portion of an anticline.

Cossington railway-cutting.—Mr. J. F. Mostyn Clarke, A.M.I.C.E., has described the sections on this railway, obtaining the details which he recorded as the construction of the line proceeded.[1]

When Mr. H. B. Woodward visited the section, he was accompanied by Mr. Clarke. Mr. Woodward noticed a bed resembling the Cotham Marble in texture, but did not attempt any detailed separation of the deposits, nor did he indicate in his record where the *Pteria-contorta* Shales ended or the 'White Lias' began.

The details appended below were obtained in the eastern bank of the cutting, alongside the goods-siding. A greater thickness of the Black Shales was formerly exposed, but talus has accumulated and has hidden a band of nodules that probably corresponds to Bed 9 in the Dunball section.

SECTION IN COSSINGTON RAILWAY-CUTTING.

			Thickness in feet	*inches.*		
LANGPORT BEDS.		Limestone in two beds, rather rubbly in between .... seen	1	0		
					1	0 seen.
COTHAM BEDS.		Clay, brown and dark grey: 2 to 4 inches	0	3		
	1.	Cotham Marble	0	2		
	2.	Shales, yellow and grey marly, very clayey at the top	3	0		
	3.	Limestone, hard, with a nodular bed occasionally on the top	0	5		
	4. (1)	Shales, pale-yellow, marly	0	4		
	4. (2)	Limestone: 2 to 4 inches	0	2		
		Shales, yellowish: 0 to 2 inches ...	0	1		
		Limestone, rather 'flaggy' with clay in the bedding-planes	0	7		
	4. (3)	Shales, yellow and brown, clayey .	0	3		
					5	3

---

[1] Proc. Bath Nat. Hist. & Antiq. F.-C. vol. vii (1891-93) pp. 127-36 [& section].

[Cossington.]

			Thickness in *feet*	*inches.*	
Westbury Beds.	5 *a.*	(1) Shales, black, laminated	2	6	
		(2) Limestone, earthy, ferruginous	0	1½	Saurian bone.
		Shale, black: 1 to 2 inches	0	1½	*Chlamys valoniensis* (Defrance).
		Limestone, shelly, nodular: 0 to 4 inches	0	2½	
		'Beef'	0	1½	
		(3) Shales, black: 12 to 18 inches	1	3	
	5 *b.*	Limestone, earthy, shelly, with 'beef' on the top	0	6	
	6.	Shales, black	1	0	
	7.	Limestone, earthy, with one or two layers of 'beef' on the top	0	5	
	8.	Shales, black			
			6	3	seen.

Indications of lower beds were obtained on the escarpment at Cock Hill, where, at the point at which the by-road from Chilton-upon-Polden leaves the main road, an excavation made in connexion with extensions to a house revealed Black Shales with pieces of rock full of fish-remains (Bed 15).

The rock was of two types. The one was a black indurated mud with *Acrodus minimus*, *Gyrolepis alberti*, *Saurichthys (?)*, small coprolites and quartz-pebbles—very much the same as the fossiliferous indurated black shale above the Bone-Bed at Lilliput, near Chipping Sodbury, Glos. (see Q. J. G. S. vol. lx, 1904, p. 197). The other type was more of the typical Bone-Bed facies, being a hard, grey, micaceous sandstone, as at Charlton Mackrell and Langport, with the usual fish-remains.

Almost in front of the 'tower' a road descends the escarpment, and in the area between it and the Bridgwater Road were found pieces of a yellowish micaceous sandstone-layer similar to Bed 19 at Langport.

In the neighbourhood of Edington and Catcott there are three quarries in work, namely:

(1) the 'Catcott Quarry,' which is situated just over half-a-mile south-by-east of Catcott Church;
(2) the 'Edington Quarry,' which is about half-a-mile west-north-west of Catcott Quarry; and
(3) another quarry, a little over a quarter of a mile north of the latter.

In the first two, the uppermost beds of the White Lias proper are seen with the basement-beds of the Lower Lias above them; while in the third, only the White-Lias 'Dew-Stones' occur.

Some care is required in fixing the line of demarcation between the Rhætic and the Lias in this neighbourhood; but the White Lias proper is only thin, as was shown by a very interesting section in a quarry in a field by the side of the Bridgwater Road, about half-a-mile north-east of Greinton. When I first visited this section, the quarry was being worked along the strike of the beds and also along a fault-line. On the south side of this fault were the Lower Liassic beds and the Dew-Stones—the beds nearest the fault being vertical, but the others soon declining away from it. On the other side of the fault, the Cotham Marble was seen bent round in a peculiar horseshoe curve. On my next visit the quarry had been developed, and this interesting bit of faulting obliterated; but the

Cotham Marble could still be seen, with its peculiar tough clay-bed above.

Glimpses of certain of the Rhætic deposits have been obtained between Lower Pedwell and the Somerton Road, and details are recorded in the Geological Survey Memoir.[1] The only matter of note is that 'shelly limestone similar to the Wedmore Stone' was observed in a ditch-excavation near a new house west of Ashcot.[2]

Windmill-Hill Quarry, Butleigh.—At Windmill Hill, close to the Butleigh Monument, is an important section. It is important because the sequence of beds is identical with that which was only temporarily exposed in the railway-cutting at Somerton to be noticed shortly; and, while the latter is probably already obscured, the former will remain open for certainly some years to come, as the quarry is 'in work.'

SECTION IN WINDMILL-HILL QUARRY, BUTLEIGH.

			Thickness in feet	*inches.*	
LOWER LIAS.	42.	Limestone, somewhat nodular, débris of.	0	4	*Ostrea liassica* Strickland.
	41.	Clay, greyish-green	0	2	
	40.	Limestone, rather flaggy	0	3	
	39.	Shale, brown and grey, laminated	0	5	
	38.	Limestone, grey and brown, fissile	0	4	
	37.	Shale, brown and grey	0	2	
	36.	Limestone, fissile, grey	0	4	
	35.	Shale, pale-brown	0	3	
	34.	Limestone, pale-brown and grey	0	4	
	33.	Marls, greyish-green with a whitish zone.	1	3	
	32.	Limestone, pale blue-grey, yellow exterior	0	8	
	31.	Shales, with a conspicuous brown seam near the centre	2	0	
	30.	Limestone, dividing into two beds	0	9	
	29.	Shale, pale	0	2	
	28.	Limestone, rather massive [8]	0	10	
	27.	Shale, brown and grey-blue [clay 5]	0	5	
	26.	Limestones, two beds: 6 to 10 inches [one bed in the Somerton cutting]	0	8	*Ostrea liassica.*
	25.	Shale, pale-brown and blue-grey, passing in places into limestone [7]	0	6	
	24.	Limestones, two beds with shale-partings	0	9	
	23.	Shale, pale-brown and blue-grey, with a half-inch limestone-bed [5]	0	7	
	22.	Limestones, three beds with shale-partings [7]	1	2	
	21.	Shale, brown [parting]	0	2	Lignite.
	20.	Limestone, hard blue [6]	0	4	
	19.	Shale, brown	0	2	
	18.	Limestone, hard blue	0	4	
	17.	Shale; 0 to 2 inches	0	1	
	16.	Limestone, hard blue	0	5	
	15.	Shale, blue and brown; 3 to 5 inches [2]	0	4	
	14.	'Blue Clog.' Limestone, massive blue.	1	0	*Ostrea liassica.* *Hemipedina*-radioles.
	13.	Shale, tough blue	0	6	
	12 to 10.	Limestones, bluish-grey, with but very thin partings: seen	2	6	

---

[1] 'Geology of East Somerset & the Bristol Coal-Fields' (1876) pp. 85–86.

[2] *Ibid.* p. 85.

One of the most noticeable features in the landscape of this part of Somerset is the Butleigh Monument, raised to the memory of Admiral Sir Samuel Hood. In its neighbourhood the ground is very much faulted, the Lias being on a level with the Red Marls. This is easily seen from the high ground near the quarry, at the cross-roads north-west of the Monument. On the left is the quarry, and by the side of the road, facing the observer, appear the Keuper Marls. Tea-green Marls are poorly exposed in the path below the Monument, and Cotham Marble has also been observed (*loc. cit.*).

Dundon-Hill outlier.—Dundon Hill is a very conspicuous outlier to the south-west of the Butleigh Monument. On the summit are two quarries, but the strata are very much disturbed, being at the south-western end of the south-western quarry bent into several little anticlines. The prevalent dip is south-eastwards. The highest bed seen in the Dundon quarries is that corresponding to Bed 34 in the Windmill-Hill Quarry. In the road leading up the hill from Compton Dundon, the Red and Tea-green Marls are finely exposed: then there are traces of the *Pteria-contorta* Shales; but by far the most interesting discovery was that of an exceedingly well-bored, nodule-shaped mass of Cotham Marble in its proper stratigraphical position, with numerous specimens of *Dimyodon intus-striatus* adhering to it. The borings are crypts of *Lithophagi.*

Butleigh-Hill Quarry.—Continuing along the Charlton-Mackrell road from Windmill Hill, the observer will notice two quarries, both on the north side of the road, and about half-a-mile apart. The first is about a mile distant from the Monument; but the second will be considered first, because it affords the better section.

In this quarry many of the limestone-beds are rich in pyrite, which, when decomposed, gives rise to cavities that impart a very cavernous appearance to those beds.

SECTION IN BUTLEIGH-HILL QUARRY.

			Thickness in feet	inches.	
Langport Beds.	11 to 15.	Limestones, whitish, in three layers, the median being the thinnest. Owing to their proximity to the surface, they are somewhat broken up	1	1	
	16.	Marl, greyish-white, with an earthy impersistent limestone-bed	0	8	
	17.	Limestone, white	0	4	
	18.	Marl, greyish-white, clayey	0	1	
	19.	Limestone of a grey tint, and rather cavernous	0	1½	
	20.	Marl, greenish-grey and brownish, clayey	0	2½	*Ostrea liassica* Strickland, *Protocardia*, *Volsella minima* (Moore).
	21.	Limestone, hard, blue and brown-centred, cavernous appearance	0	3	
	22.	Marl, greenish-grey and white	0	7	*Ostrea liassica*, *O.* cf. *irregularis* Münster, *Dimyodon intus-striatus* (Emmerich), *Plagiostoma valoniense* (Defrance), *Cardinia* sp. indet. *Volsella minima.*
	23.	Limestone, rather earthy	0	3	
	24.	Marl, whitish and often pale-brown	0	6	

		[Butleigh Hill.]	Thickness in feet	inches.	
Langport Beds (continued).	25.	Limestone, whitish-brown, dividing into two beds of which the lower is very shelly	0	10	*Pleuromya crowcombeia* auctt.
	26.	Marl; 5 to 6 inches	0	6	*Pleuromya crowcombeia*, *Amberleya (?)*.
	27.	Limestone, white, earthy	0	2	
	28.	Marl, greyish-green, laminated	0	1	
	29 to 32.	Limestones and marl	1	2	
	33.	Limestone, irregular, blue-hearted	0	4	
	34.	Marl, indurated: 3 to 5 inches	0	4	
	35.	Limestone, irregular; 4 to 6 inches	0	5	
	36.	Marl and stone: 1 to 2 inches	0	1	
	37.	Limestone, whitish, soon breaks up: 8 to 10 inches	0	9	
	38.	Limestone, impure (6 inches), and marl	0	7	
	39.	Limestone, massive, white	1	1	

Charlton-Mackrell railway-cutting.—The next section to be noticed is the extraordinarily fine one that was opened out during the construction of the Castle Cary & Langport Railway at Charlton Mackrell. It has been briefly referred to by Mr. H. B. Woodward[1]; but Mr. E. T. Paris and I spent a considerable time in studying it in detail, and the following record is the result:—

			Thickness in feet	inches.	
LOWER LIAS.		Greyish-blue flaggy limestone:—seen	0	8½	
		Marl, yellowish: 8 to 10 inches	0	9	
		Limestone, fissile, grey-brown	0	3	
		Marl and thin limestones	0	6	
		Limestone, grey, fetid, very regular bed	0	3	
		Pale yellow clayey marl	0	4½	
			2	10	
		Non-sequence.			
UPPER RHÆTIC.	1.	'Sun-Bed.' Limestone, soon breaks up	0	8	
	2.	Shale, marly, often indurated	0	8	*Ostrea liassica* Strickland. *Volsella minima* (Moore).
	3.	Limestone, very regular. 'Block-Bed'	0	5	
	4.	Rubbly limestones and marls	1	11	*Ostrea liassica*, *Volsella minima*.
	5.	Limestone, often divides into two beds	0	11	
Langport Beds.	6.	Shale	0	1	
	7.	Limestone, massive	0	9	
	8.	Shale, marly	0	4½	
	9.	Limestone, often separates into two beds	0	9	
	10.	Shale-parting	0	0¼	
	11.	Limestone	0	5	
	12.	Shale	0	0½	
	13.	Limestone	0	2	
	14.	Shale	0	0¼	
	15.	Limestone	0	3½	
	16.	Shale	0	1½	*Ostrea liassica*.
	17.	Limestone, irregular	0	5	
	18.	Shale	0	0½	
	19.	Limestone, impure	0	2½	
	20.	Shale	0	1	
	21.	Limestone, hard, conchoidal fracture, ferruginous	0	3	
	22.	Marl and limestone	0	2	
	23.	Limestone	0	2	
	24.	Limestone and shale	0	4	
	25.	Limestone, very ferruginous along the joints	0	4	

---

[1] 'Summary of Progress for 1904' Mem. Geol. Surv. 1905, p. 165.

		[Charlton Mackrell.]	Thickness in feet	inches.	
UPPER RHÆTIC (*continued*). Langport Beds (*continued*).	26.	Rocky marl	0	7	
	27.	Limestone, massive, often in three layers, the top and bottom layers being very shelly. Towards the eastern end of the cutting, they conjoin and are crowded with a branching coral. This is Bed 29 of Moore's Steven's-Hill section, Long Sutton	1	4	*Thecosmilia (?) michelini* Terq. & Piette, and *Ostrea liassica*, abundant.
	28.	Pale-brown and green marly shale	0	4	*Cardinia* sp. (internal cast). *Nuculana (?)*, *Plagiostoma valoniense* (Defrance), *Ostrea liassica*.
	29.	Limestone	0	2	
	30.	Shale	0	0½	
	31.	Limestone	0	4	
	32.	Shale	0	0½	
	33.	Limestone	0	3	*Volsella minima* and varieties.
	34.	Marl and limestone	0	5½	*Volsella minima*, *Syncyclonema* sp.
	35.	Limestone	0	4½	*Cardinia* sp. (int. cast), *Myoconcha (?)* sp., *Gervillia præcursor* Qu., *Pseudomelania (?)*, *Pleurotomaria* (very depressed form).
	36.	Marl and limestone	0	3½	
	37.	Limestone, hard, conchoidal fracture	0	6	
	38	Marl and rubbly limestone	0	8	*Plagiostoma valoniense*, *Volsella minima*, *Pholadomya* (of *Ph.-glabra* group ?).
	39.	Limestone, cream-coloured, very massive, often giving off a 3-inch bed at the base	1	8	
	40.	Parting of shale	0	0½	
	41.	Limestone, cream-coloured	0	1½	
	42.	Greenish-yellow marly shale and some limestone fitting into the inequalities of the underlying bed.	0	1	
	43.	Limestone, massive, cream-coloured, with some veins of calcite: top very irregular	0	11	
	44.	Pale greenish-yellow shaly marl and some rubbly sandstone	0	4	
	45.	Limestone, cream-coloured, level top, most irregular nether surface, fitting into the inequalities of the underlying bed, with a little shale intervening	0	2½	
	46.	Limestone, very massive, some veins of calcite, most irregular surface, apparently waterworn	0	11	
	47.	Greenish-yellow marly shale:	0	0½	
	48.	Limestone, hard, cream-coloured, with pyrite	0	2½	
	49.	Thin impure limestone-layers and marly shale, pale yellowish-green	0	5½	*Protocardia*.
	50.	Limestone, massive, rather irregular, yellow and grey-brown	0	8	
					20 8
Cotham Beds.	1.	Brown marly clay [Stratigraphical position of the Cotham Marble.]	0	3	
	2.	Shales, dark-grey and green, marly	2	2	Fish-scales.
	3.	Limestone, fine-grained, light-grey with darker streaks of more crystalline rock	0	4	
	4. (1)	Shales, yellowish and greenish-grey, with thin limestone-layers often conjoined to form a single massive bed	1	0	
	(2)	Limestone, hard, yellowish-grey: average	0	6	
	(3)	Thin yellowish arenaceous limestone, mixed with some marl, and having at the base a very pyritic layer	0	6	
					4 9

[Charlton Mackrell.]			*Thickness in feet*	*inches.*	
		[Below the pyritic bed occurs in some places hard, blackish, crystalline, shelly limestone (with a layer of 'beef') 5 inches thick; in others, greenish-looking marl in lenticular masses. In yet other places, immediately below the pyritic bed are the black shales of the Lilstock Beds, containing at the very top huge masses of very hard black and grey crystalline limestone, sometimes as much as 2 feet thick, and containing (though rarely) *Chlamys valoniensis*, *Isocyprina ewaldi*, *Cardinia concinna* Sow., aff. *regularis* Terq., Vaughan, *Gyrolepis alberti* Ag., and fish-vertebræ.]			[Compare Sparkford-Hill section, p. 48, and St. Audrie's Slip, pp. 22 & 25.]
LOWER RHÆTIC. Westbury Beds.	5 *a*. (1)	Shales, black, thinly laminated, with one or two very thin layers of pyritous grit	2	3	At the very top the following were abundant: *Chlamys valoniensis* (Defrance), *Pteria contorta* (Portlock), *Placunopsis alpina* Winkler, *Isocyprina ewaldi* (Born.), and *Cardium cloacinum* Quenstedt.
	(2)	Limestone, black, earthy, mixed with shale, slightly arenaceous ...	0	4	*Chlamys valoniensis*, *Placunopsis alpina*, and *Volsella (?) minuta* (Goldfuss), scales and teeth (?) of *Gyrolepis*.
	(3)	Shale, black, and similar limestone	0	4	Same fossils as in 5 *a* (1).
	5 *b*.	Limestone, hard, dark grey, crystalline, very shelly	0	2½	*Volsella sodburiensis* (Vaugh.), *Pteria contorta*, *Cardium cloacinum*, *Isocyprina ewaldi*, *Placunopsis alpina*, *Protocardia rhætica* (Merian), scales of *Gyrolepis alberti* Ag.
	6.	Shale, black, with some earthy limestone	0	2	Same fossils as in Bed 5 *b*.
	7.	Limestone, black, earthy, with a layer of 'beef' on the nether surface	0	3	
	8.	Shales, black, thinly laminated ...	3	0	
	9.	Limestone, massive, grey, calcite and selenite present, septariform: 4 to 10 inches	0	7	Shelly.
	10 to 12.	Shales, black, thinly laminated: about	7	0	
	13.	Black and grey indurated, arenaceous, micaceous shale passing into hard black shale	0	5	Numerous coprolites and fish-remains.
	14.	Shale, black	0	0½	
		Deposit similar to 13 but more persistent, not passing into black shale	0	6	
		Hard greenish and black arenaceous shale	0	1½	
	15.	Hard greenish, sandy, micaceous limestone	0	5	
		Black shale-parting	0	0½	
		Hard grey siliceous sandstone. The principal **Bone-Bed**. 4 to 8 inches	0	6	*Acrodus minimus* Ag., *Gyrolepis alberti*, *Lepidotus ?* (teeth), saurian tooth, coprolites, small quartz-pebbles.
	16.	Shales, black, non-laminated, greenish zone near the organic remains.	0	7½	*Pteria contorta* common.
	17.	Limestone-nodules, hard, greyish, somewhat crystalline: 0 to 3 inches	0	1½	
	18.	Shales, black, imperfectly laminated	3	4	
	19.	Indurated, greenish-streaked, black, sandy shale, crowded with fish-remains and small quartz-pebbles.	0	3	Lignite abundant.
	20.	Shales, black, non-laminated, streaked with irregular white sandstone-layers	1	6	
		Grey, indurated, sandy mudstone passing up into the overlying bed.	0	4	Full of fish-remains—*Acrodus minimus*, *Gyrolepis alberti*, *Lepidotus ?* (teeth), and small quartz-pebbles.
		Non-sequence.			
KEUPER.		'Tea-green Marls.' Pale yellowish-green rocky marls.	22	4	

The bottom-beds of the Lower Lias that were seen, corresponded precisely with the similarly-numbered deposits exposed in the cutting on the west-north-west—that through which the line passes immediately before crossing the Cary River.

The Langport Beds were exposed in their entirety, measuring 20 feet 8 inches. A bed crowded with the branching coral *Thecosmilia*, and comparable with that noticed by Moore at Long Sutton many years ago,[1] constituted a notable horizon. Here the Langport Beds fall naturally into five groups—the massive 'Sizes' at the base, and the more rubbly beds near the top. Even in this fine development there is oft-recurring evidence of slow formation afforded by the waterworn and channelled surfaces of the massive 'Sizes,' and by the manner in which the specimens of *Dimyodon intus-striatus* adhere to the upper surface of the limestones and encrust the pebbles in the intervening marly layers.

The Cotham Marble was not detected, but its stratigraphical position was obvious, and it was discovered at that horizon in the cutting near the Cary River (see p. 45).

Between the Cotham and the Lilstock Beds occur locally huge masses of hard limestone coated with shell-débris. Similar masses occur at Sparkford Hill on this horizon, and emphasize the temporary discontinuance of sequential deposition—of which evidence was also afforded at St. Audrie's Slip near Watchet.

Bed 9 was a readily-recognized and conspicuous stratum, for its large septariform nodules were scattered over the floor of the cutting at the foot of the bank, down which they had rolled.

The Bone-Bed (15) at Charlton Mackrell is a hard grey siliceous sandstone, intermediate as regards texture between the Bone-Bed of the Blue-Anchor foreshore and that at Lilstock. Streaks of impure, grey, micaceous limestone traverse the bed; but in such vertebrate-remains are few, being most abundant in the sandstone-portion.

The basal Bone-Bed (20, lower part) is a grey indurated sandy mudstone, with flakes of marl which impart to it a laminated appearance.

Cary-Bridge cutting.—Continuing along the railway in the direction of Somerton, a cutting through a highly-faulted outlier of Rhætic and Liassic rocks is traversed before reaching the viaduct over the Cary.

Entering the north-eastern end of this cutting, we perceive first of all traces of the red marls, with the *Pteria-contorta* Shales faulted against them. Then succeed prominent limestones about the horizon of stratum 3 of the Cotham Beds, followed by bluish shales as at Charlton Mackrell. Above is the whole of the Langport Beds with the prominent *Thecosmilia* Bed about their middle,

---

[1] Q. J. G. S. vol. xvii (1861) pp. 491–92.

Fig. 2.—*Sparkford Hill section (diagrammatic).*

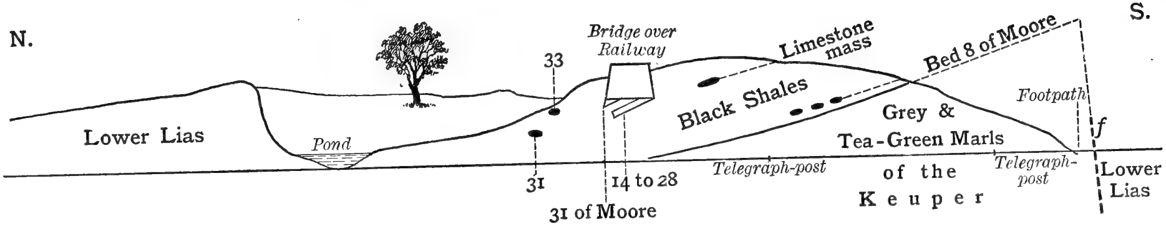
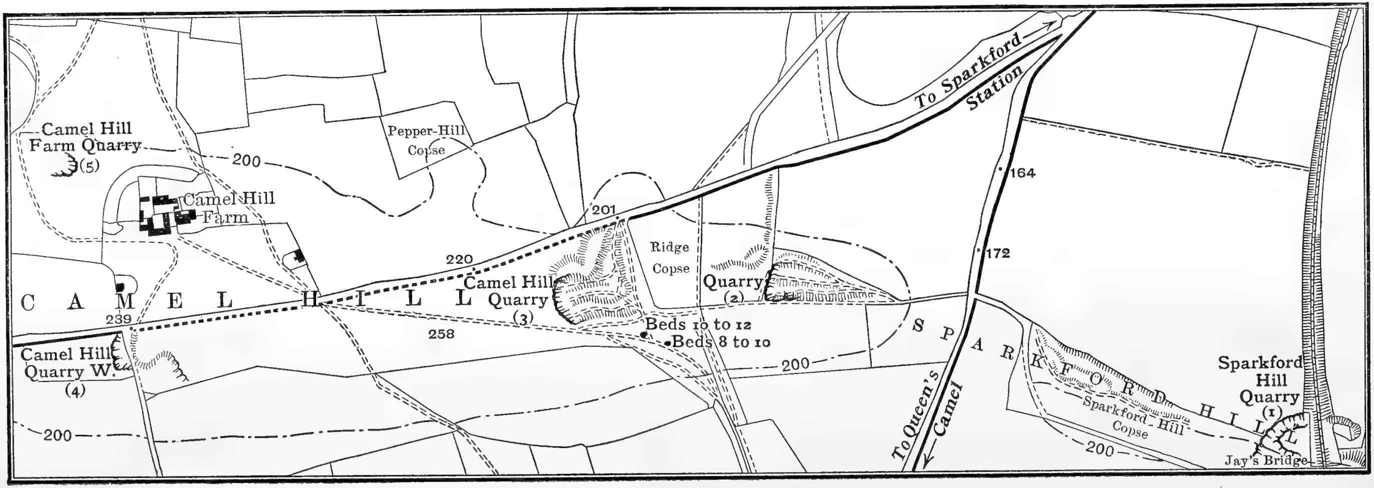


Fig. 3.—*Map (on the scale of 6 inches to the mile) showing the positions of the quarries at Sparkford Hill and Camel Hill.*



and the Sun-Bed—more massive than at Charlton—at the top. Then come the following Lower Liassic deposits:—

Section in Cary-Bridge Railway-Cutting.

			Thickness in feet	*inches.*
LOWER LIAS.	14.	Limestone, massive, blue, separating into several beds: seen...	1	2
	13.	Shale, pale-brown and grey	0	7
	12.	Limestone	0	4½
	11.	Shale, brown	0	2
	10.	Limestones, bluish: three beds with shale-partings	1	9
	9.	Shale, grey and pale-brown	0	9
	8.	Limestone, fissile, blue-hearted	0	7
	7.	Limestone, thin-bedded, shaly	1	5
	6.	Limestone, fissile, massive, bluish-grey	0	8
	5.	Shale, blue-grey, passing up into the bed above	0	8
	4.	Limestone, brown and blue-hearted	0	3
	3.	Shale, blue-grey, hard, papery	0	1
	2.	Limestone, emitting a fetid odour when struck	0	3
	1.	Shale, papery	0	5

Langport Beds. Sun-Bed.

Bed 14 is the 'Blue Clog'—No. 14 of the Windmill-Hill section at Butleigh (p. 38). Thence upwards to Bed 31 the sequence is the same as that which is exposed at Windmill Hill, with the differences in thickness noted in square brackets in the Windmill-Hill record.

In the Cary-Bridge cutting these Lower Liassic beds are affected by a slight overthrust-fault, and are placed in juxtaposition with the Cotham and Langport Beds. Here the Cotham Marble (4 inches) was discovered *in situ*, and it exhibited that incipiently-conglomeratic facies which has earned for it the name of 'false Cotham'.[1]

(B) The Sparkford Hill Area.

(i) Introduction.—North of Queen's Camel, near Sparkford, is a stretch of elevated ground bearing the names of Sparkford Hill and Camel Hill. From the general geology it is obvious that this inlier owes its genesis to anticlinal folding and subsequent faulting: the anticline being doubtless a continuation of that to which I referred when dealing with Blue Anchor Point and the Polden Hills.

The inlier is cut through by the Great Western Railway, and when the line was made a very fine section was exposed.

(ii) Stratigraphical Details.

Sparkford Hill railway-cutting.—This fine section is now, however, mostly overgrown; fortunately, it was described in

---

[1] For the guidance of future observers, it may be as well to state that, when the banks of the deep cuttings on this line had been smoothed down, red sandy material was frequently spread over the sides. From a distance, this led one to think that the cutting was wholly in the red marls, instead of in a variety of deposits (Rhætic or Liassic, or both).

detail by Charles Moore,[1] of whose record an abbreviated edition appears in the Geological Survey Memoir on 'The Lias of England & Wales (Yorkshire excepted)'.[2]

The section (fig. 2, p. 44) will give some idea of all that can be seen in the way of beds in the eastern side of the cutting. The Grey and Tea-green Marls are not well exposed now; but the band of white gypsum, erroneously identified by Moore as 'strontian,' can be made out, as well as the 'thinly laminated grey marl' of his record.

It will perhaps be best to give here a statement of the beds that are present in the inlier. Details of the Keuper marls and of the Rhaetic beds, up to the topmost deposits of the Cotham Beds, were derived from the cutting: the lowermost strata of the Langport Beds are not exposed; but the remaining beds are excellently seen in the large Camel-Hill Quarry (No. 3 on the map, fig. 3, p. 44).

Sequence of Deposits in the Sparkford Inlier.

Camel-Hill Quarry.

				Thickness in feet	*inches.*	
'Planorbis Zone.'	122	42	'Sandrock' Limestone, breaking up into peculiar oblong pieces	0	3½	
	121	41	Clay, blue and yellowish...............	1	0	
	120	40	'Sandrock': average	0	7	*Caloceras johnstoni* (Sow.).
	119	39	Shale: 1 to 5 inches	0	3	
	118	38	'Sandrock': 2 to 6 inches	0	4	*C. johnstoni* and *Ostrea liassica* Strickland.
	117	37	Shale: average	0	2	
	116	36	'Sandrock': 0 to 6 inches	0	3	
	115	35	Shale: average	0	4	
	114	34	'Sandrock.' Bluish, fissile, having peculiar tubular perforations filled with iron-oxide; 2 to 8 inches ...	0	2	
	113	33	Shale	0	2	*Psiloceras planorbis* (Sow.).
	112	32	'Slippery Bed' Limestone	0	8	
	111	31	Shales, yellowish	2	6	*C. johnstoni*, *Ps. planorbis*, *Ostrea liassica*, etc.
	110	30	'Sandrock'	1	0	*Psiloceras planorbis*, etc.
	109	29	Shale: average	0	5	
	108	28	'Sandrock'; 0 to 4 inches	0	2	*Radula pectinoides* (Sow.).
	107	27	Shale, hard	0	5	*Hemipedina* radioles, etc.
	106	26	'Sandrock'	0	8	Very fossiliferous.
	105	25	Shale: average	0	4	
	104	24	Sandrock	0	4	
Ostrea & Saurian Beds.	103	23	Shale, bluish	0	6	*Volsella minima* (Sow.).
	102 to 94	22 to 16	Eight beds of 'Firestones' (limestones) with shale-partings	4	4	Few fossils.
	93	15	Shale: average	0	1	
	92	14	Limestone	1	0	*Ostrea liassica* abundant.

---

[1] Q. J. G. S. vol. xxiii (1867) pp. 461–64.

[2] 'Jurassic Rocks of Britain' vol. iii (1893) pp. 77–79.

[Camel-Hill Quarry.]

				Thickness in feet	inches	
Insect and Crustacean Beds.	91	13	Marl	0	2	
	90	12	'Insect-Limestone.' 'Cap': average	0	4	
	89	11	Shale: 0 to 2 inches	0	2	
	88	10	'Hat and Cap' Limestone: 4 to 8 ins.	0	6	
	87	9	Shale: 0 to 3 inches	0	2	
	86	8	Limestone: 2 to 6 inches	0	4	
	85	7	Shale; average	0	2	*Eryon.*
	84	6	'Insect-Limestone'	0	6	
	83	5	Shale, hard	0	2	*Eryon wilmcotensis* Woodw.
	82	4	'Insect-Limestone'	0	6	
	81	3	Shale	0	3	
	80	2	Insect-Limestone	0	6	Insect-remains.
	79	1	'Paper-Shales'	0	4	
			[Position of Watchet Beds.]			
Langport Beds.	78		'Sun-Bed' Limestone	1	4	
	77		Marl: average	0	1	
	76		'Block-Bed' Limestone	1	2	
	75		Limestone	0	7½	
	74		Limestone	1	0	
	73		Shale	0	0½	
	72		Limestone	0	2	
	71		Shale	0	0½	
	70		Limestone	0	2½	
	69		Shale	0	1½	
	68		Limestone, rubbly, and marl	1	4	
	67		Limestones	2	1	
	66		Shale	0	2	
	65		Limestone; has a yellower appearance than the other beds	0	4	
	64		Shale	0	3	
	63		Limestone	0	2½	
	62		Shale	0	2	
	61		Limestone: average	0	8	
	60		Shale	0	1	
	to 56		Limestones with marl partings	2	5	
	55		Limestone	0	3½	
	54		Shale	0	1	
	53 to 45		Limestones, more rubbly	3	0	*Plagiostoma valoniense* (Defrance), ostracoda.
	44		Shale and pebbles	0	5	
	43		Limestone, massive	0	11	
	42-41		Limestone often in two beds	1	4	
	40		Limestone: seen	0	3	
			[Not exposed in the quarry, but tabulated on Moore's authority.]			
	40		Limestone; remainder	0	3	
	39		Shale	0	1	
	38		Limestone	0	6	
	37		Limestone	0	7½	
	36		Limestone	0	5	
				20	8	

Section in Sparkford-Hill Railway-Cutting.

Cotham Beds.		?1	? Position of Cotham Marble.			
	35	?2	Marl (*teste* Moore)	10	7	
	34		Limestone, pale, fissile	0	0	
	33	3	Limestone, greenish, concretionary	0	9	
	32		(1) Marls, pale green, shaly: av..	2	9	
	31		(2) Limestone	0	6	
	30	4	3 Limestone and shale	0	2	Fish-scales.
	29 (*pars*)		Marl, brownish-yellow	0	2	
				14	11	

			[Sparkford Hill.]	*Thickness in feet*	*inches.*	
Westbury Beds.			[Here comes apparently the line of hard greyish-green crystalline limestone-masses, of which one boulder-like mass is seen projecting through the turf.]			
	29 to 17	(*pars*) 5 *a*	Shales, black, laminated: av. Series of thin limestones and shales	1 1	9 6½	Usual fossils of the *Pteria-contorta* Beds.
	16	5 *b*	Limestone, with 'beef' below	0	3½	
	15	6	Shale, black	0	2	
	14	7	Limestone	0	3	
	13	8 to 10	Shales	24	6	
	12[1]	11	Sandstone	2	0	*Gyrolepis alberti* Ag.
	11	12	Marly deposit	0	5	
	10	13	Sandstone	1	0	
	9	14	Marly deposit	0	8	*Acrodus minimus* Ag., *G. alberti* (scales and teeth), *Isocyprina* sp. indet., etc.
	8[1]	15	Sandstone	1	6	
				34	1	
			[Position of Sully Beds.]			
Keuper.			Marls, greyish, with a few layers of gypsum: seen (*teste* Moore)	80	6	

No additional information with regard to the Westbury and Cotham Beds supplementing that given in the above record is necessary.

Camel-Hill Quarry (3) exhibits the sequence of deposits from Bed 40 to 122 of Moore. Moore's numbers were applied to the beds that he saw in the railway-cutting, so it will be understood how persistent are the individual layers in this inlier.

There is no need for a detailed notice of this section at Camel Hill: all the stratigraphical information that can be required is given in the record on pp. 46–47; but it may be as well to emphasize the point that the local Insect and Crustacean Beds are very distinctive deposits, and occupy a position in this neighbourhood inferior to the Saurian and *Ostrea* Beds.

In the quarry distinguished as 4 on the map (fig. 3), the highest bed seen is Bed 84 of Moore and the lowest his Bed 71. The Sun-Bed is a 'ragged' rock with longitudinal borings, and is overlain by clay, the bottom layer of which is of a conspicuous chocolate colour.

In Quarry No. 5, the white limestones of the Langport Beds are seen at the base, and then above them come beds corresponding to those numbered 79 to 92 (according to Moore's notation) of the Camel-Hill section.

In Quarry No. 2, the yellow bed (65) is at the top, and below a succession similar to that at Camel-Hill Quarry can be made out.

In the wood close to the railway-cutting is the Sparkford-Hill Quarry. The Langport Beds are very fossiliferous at certain horizons, and have yielded *Pseudopedina tomesi* (Wr.), *Cardinia* sp., *Plagiostoma valoniense* (Defr.), *Dimyodon intus-striatus* (Emmerich), *Grammatodon lycetti* (Moore), ostracods, etc. The lowest beds visible are the massive limestones in the neighbourhood of Beds 41 to 43. By following up the section, the same horizons and deposits as at Camel Hill can be distinguished, and the massive-looking stratum

---

[1] Beds 11 to 15 (or 8 to 12 of Moore) are seen cropping out in the side of the track near Camel-Hill Quarry (see map, fig. 3); there however, Bed 13 is not a sandstone, but a fossiliferous limestone like Moore's 'Flinty Bed' of Crocombe.

near the top is the 25-inch bed which comes above the 'yellow-bed horizon' (65). Following the excavation in the direction of the dip, we come upon the Insect and Crustacean Beds, then the Saurian Beds and all the deposits up to Bed 122, which, as at Camel-Hill Quarry, breaks up into peculiar little oblong pieces.

(C) The Somerton-Langport Area.

(i) Introduction.—The principal section in the area is in the railway-cutting south-west of the Union at Langport, and will be considered first. It has been very briefly noticed by Mr. H. B. Woodward.[1]

(ii) Stratigraphical Details.

Langport railway-cutting.—In the approach to Langport Station greenish marls with pinkish zones, reminiscent of the Lavernock section, near Cardiff, are exposed.

From the Station to half-way between the first and second bridges similar greenish marls, but with harder white zones, are exposed. At the first bridge these are capped with gravel, composed mainly of well-rolled fragments of the white limestones of the Langport Beds; while south of the second bridge is the following section:—

RAILWAY-CUTTING SECTION, LANGPORT.

				Thickness in feet	*inches.*	
UPPER RHÆTIC.	LANGPORT BEDS.	31.	Limestone, white	—		*Ostrea liassica* Strickl.
		32.	Marl	0	2	
		33.	Limestone, white	0	1	
		34.	Marl	0	3	
		35.	Limestone, white	0	1½	*Grammatodon lycetti* Moore.
		36.	Marl	0	5	
		37.	Limestone, white	0	5	
		38.	Marl and limestone, with a 2-inch layer of clay on the top	0	9	
		39.	Limestone, white, in two layers	0	7	
		40.	Marl, indurated in places	0	7	
		41.	Limestone, white	0	4½	*Gervillia præcursor* Qu., *Plagiostoma valoniense* (Defr.), *Dimyodon intus-striatus* (Emmerich).
		42.	Marl and rubble	0	2	
		43.	Limestone, white	0	4	
		44.	Marl and rubble	0	3½	
		45.	Limestone, massive, white	0	11	*Protocardia* (internal cast).
			Marl and rubble	0	3	
		46.	Limestone, massive, white	1	2	Crypts of *Lithophagus*.
		47.	Marl	0	2	
		48.	Limestone, rubbly	0	4	*Ostrea liassica*.
		49.	Marl	0	2½	
		50.	Limestone, greyish-white, rubbly	0	8	
			Seen	8	3	
	COTHAM BEDS.		Shale, bluish-grey & brown, clayey.	0	2	
		1.	Cotham Marble	0	2	
		2.	Shales, bluish-grey, with thin layers of 'beef'	2	5	Ostracoda at the top.
		3.	Limestone, hard, bluish-grey: 4 to 8 inches	0	6	
		4. (1)	Marl, bluish-grey and pale yellow, indurated in places	0	10	
		(2)	Limestone, hard, bluish-grey and yellowish, with a layer of 'beef' immediately below it	0	6	
		(3)	Marl, pale greenish-grey, sandy	0	5	
				5	0	

---

[1] 'Summary of Progress for 1904' Mem. Geol. Surv. 1905, pp. 163–68.

[Langport.]				*Thickness in feet*	*inches.*	
LOWER RHÆTIC.	Westbury Beds.	5 *a*.	Shales, black and grey, laminated with brown layers, one being particularly noticeable about the centre: 26 to 32 inches	2	5	*Cardium cloacinum* Qu.
		5 *b*.	A peculiar black and ferruginous deposit, which fills in fissures in the bed below[1]	0	1	
		6.	Yellow rubble and brown earthy marl	1	3	
		7.	Limestone, hard, grey, rather sandy, breaking up into three layers, with 'beef' above and below. Baryto-celestine and pyrite: 2 to 6 inches.	0	4	*Chlamys valoniensis* (Defrance), *Pteria contorta* (Portlock), *Protocardia rhætica* (Merian).
		8.	Shales, black, ferruginous about the centre	4	0	
		9.	Limestone, dark, earthy, nodular, and where present very conspicuous, but occasionally passing into rubble	0	9	*Volsella minima* (Moore), *Protocardia rhætica*.
		10 to 12.	Shales, black and grey, well-laminated, with a few gritty seams	10	0	*Pteria contorta*, etc.
		13.	Sandstone, greenish-yellow, earthy	0	3	Fish-remains (scales).
		14.	Shale, black and yellow, clayey	0	7	*Gyrolepis alberti* Ag., coprolites, small quartz-pebbles, etc.
		15.	Sandstone, grey, impure, fine-grained, calcareous: 1 to 6 inches	0	3	
		16 to 18.	Shales, black	2	3	
		19.	Sandstone, whitish-yellow, micaceous	0	0½	Fish-remains.
		20.	Shale, black, laminated	0	9	
			Shale, black, indurated, and green marl	0	0½	Fish-remains.
			Non-sequence.			23 0
KEUPER.			Grey and Tea-green Marls. Marls, pale yellowish-green: seen	10	0	

There is nothing to remark concerning this section that is not sufficiently brought out in the above record. Bed 9 was very conspicuous, and, as usual, the individual deposits of the Cotham Beds could be readily identified.

Escarpment between Somerton and Wagg.—In this escarpment there are no exposures worthy of note; the only discovery of interest was that of typical Cotham Marble, cropping out of the bed of the rough road that climbs the hillside through Somerton Wood.

Ham Hill inlier.—The Geological Survey map represents an extensive spread of Rhætic beds to the north of Langport; but several quarries now show that the representation of the superficial extent of the Rhætic has been too liberal. In a quarry about a quarter of a mile south of Turn Hill, Lower Liassic beds similar to their equivalents at Butleigh (p. 38) were exposed: the lowest bed visible being locally called the 'Clog Stone,' and comparable with Bed 14 of Windmill-Hill Quarry. Near the old windmill between High and Low Ham the 'Sizes' of the Langport Beds are exposed; and formerly the Black Shales of the Westbury Beds could be seen above the fine exposure of the Keuper deposits at Turn Hill.[2]

---

[1] There may be a slight break here.

[2] W. Boyd Dawkins, Q. J. G. S. vol. xx (1864) p. 404.

(D) The Langport-Howley Area.

This area is represented in Sheets xviii (old series) & 311 (new series) of the Geological Survey map.

With the exception of the neighbourhood of Hatch Beauchamp, where the beds are affected by a fault, the uppermost deposits of the Keuper and the lower strata of the Rhætic crop out in a bold bank that is continuous from Langport to Pickeridge Hill. Thence south-eastwards for a space of about 5 miles the outcrop of the Rhætic is concealed under the Cretaceous rocks; but the *Pteria-contorta* Shales are seen again near Knapp Farm, in the deeply-excavated Yarty Valley.[1]

In the escarpment between Langport and Pickeridge Hill there are but few sections of the beds under consideration now open.

In the side of the track leading down the hill to Wick, the following details may be observed: at the top rubbly cream-coloured beds, belonging to the Langport Beds; a band of hard limestone [4 (2) of the Cotham Beds], which rests upon a greenish marly shale [4 (3)], and this in turn upon the Black Shales. The hard limestone in these is Bed 5 *b*. At Red Hill, the Red and Tea-green Marls of the Keuper are finely displayed; but the most interesting feature in this neighbourhood is the bored Sun-Bed.[2] Similar phenomena are to be observed at Breach Hill in East Somerset, and indicate a non-sequence. Near the Parkfield Monument and close to the main road, is a quarry in the Lower Lias opened up in beds equivalent to those numbered 30 to 38 (in my notation) at Butleigh and Camel Hill (pp. 38 & 46 respectively).

Between the Parkfield Monument and Fivehead there are no sections to record; but at the latter place—close to the main road—is a quarry in which the section represented in the appended diagram (fig. 4, p. 52) can be made out. It was interesting to find so unmistakable a representative of the Cotham Marble, here as at Dundon (p. 39) associated with some very dark sticky clay.

At Crimson Hill, near Hatch Beauchamp, the escarpment is pierced by the tunnel that allowed passage for the now almost wholly destroyed Bridgwater Canal. It was from pieces of rock that had been brought out of this tunnel and tipped near the quarries at Beer Crocombe, that Moore obtained the extraordinary suite of fossils that he described as having come from the 'Flinty Bed' of Beer Crocombe.[3] He was at first puzzled as to the precise stratigraphical horizon of this 'Flinty Bed'; so was the Rev. P. B. Brodie, who sent a selection of specimens to Wright: the latter could only suggest that it might be equivalent to the '*Cypris*-Bed,' or *Estheria* Bed as it is now called, of such Gloucestershire sections as that at Garden Cliff.[4] However, Moore came to the conclusion that the bed occurred in the '*Avicula-contorta* Zone'[5]; and, although it has been suggested that all his specimens may

---

[1] Proc. Geol. Assoc. vol. xix (1906) p. 409.

[2] See Vert. Sect. Sheet 47, No. 5 [Curry Rivell] Geol. Surv. 1873; and H. B. Woodward & J. H. Blake, Geol. Mag. vol. ix (1872) p. 197.

[3] Q. J. G. S. vol. xvii (1861) p. 486.

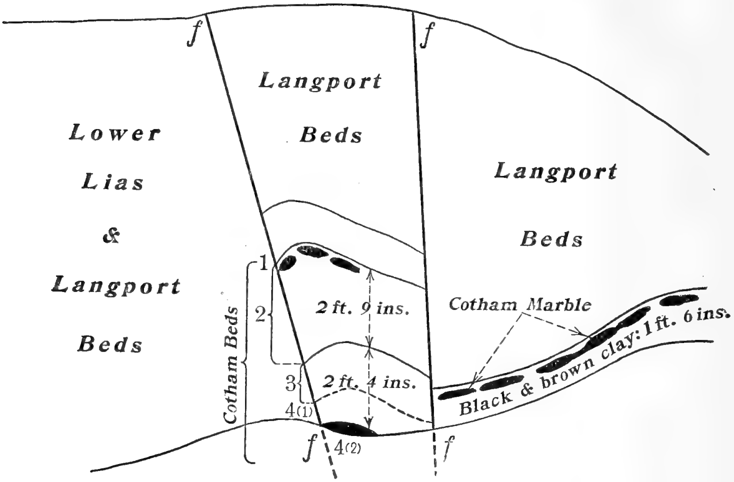
[4] *Ibid.* vol. xvi (1860) p. 384.

[5] *Ibid.* vol. xvii (1861) p. 486.

not have come from one horizon,[1] I am satisfied (after an examination of the specimens in the Bath Museum) that all so labelled did come from one horizon, and feel little doubt that that horizon is Bed 13 or the *Pleurophorus* Bed of West Somerset.

Fig. 4.

Diagrammatic Section of the Quarry at Fivehead.



The section in the railway-cutting between Hatch Beauchamp Station and the tunnel was originally investigated by Moore,[2] and later by Mr. H. B. Woodward.[3] The Westbury Beds are 22 feet 2 inches thick, and at 11 feet 10 inches above their base occurs the stratum that Moore identified with his 'Flinty Bed.' As has been remarked, it is unfortunate that he did not record any specimens therefrom.[4] The Cotham Beds are thus constituted here :—

	Thickness in feet	*inches.*
[1. Position of the Cotham Marble.]		
2. Light-blue marl	3	0
3. Grey stone with darker layers	1	2
4. Grey marl and stone	0	7

In the Geological Survey Memoir on the district, in which an abbreviated edition of Moore's record is published along with an excellent sketch-section, Mr. Woodward remarks (p. 26) that

> 'it may be questioned whether the "grey stone with layers of darker colour" and overlying "light blue marl" should not be placed with the White Lias.'

I think, however, that the interpretation given above is correct. The Langport Beds are only 9 feet 4 inches thick here, according to Moore, so they have decreased considerably in thickness.

About half-way between Stoke St. Mary and West Hatch is a large quarry, in which the uppermost strata of the Langport Beds and the

---

[1] 'The Geology of the Country between Wellington & Chard' Mem. Geol. Surv. 1906, p. 27.

[2] Q. J. G. S. vol. xxiii (1867) p. 469.

[3] 'The Geology of the Country between Wellington & Chard' pp. 25–26.

[4] *Ibid.* p. 27.

bottom-beds of the Lower Lias, here called the 'Blue Lias,' are excellently displayed. Moore measured the section, and to the extreme accuracy of his record I gladly bear witness.[1] He did not observe any exposure of the *Pteria-contorta* Shales near Stoke St. Mary; but their junction with the underlying marl may be seen in the lane east of Stoke Court.

(E) The Wedmore Inlier.

The total thickness of the Rhætic Series in this inlier has not been ascertained.

The Red Marls are exposed at many points, and at Panborough have the Tea-green Marls faulted against them. The Tea-green Marls are also visible at several places, notably in the roadsides at Bagley; while between Theal and Bagley, in Snake Lane, Red Marls, Grey and Tea-green Marls, and the *Pteria-contorta* Shales, with their associated hard beds, are exposed.

The Snake-Lane Section is not so clear as it was in the days when Prof. Boyd Dawkins investigated it[2]; but, with a little care, the following succession can be determined:—

SNAKE-LANE SECTION, NEAR BAGLEY.

				Thickness in feet	*inches.*	
WESTBURY BEDS.	[12][3]	14.	Shales, black and grey, with reddish sandy layers: seen	1	6	
	[11]	15.	The Bone-Bed. Sandstones, hard, pale grey, calcareous, in three to six layers with shale-partings. On the weathered surface is much shell-débris: average	1	2	*Acrodus minimus* Ag., *Gyrolepis alberti* Ag. (scales and teeth), *Isocyprina ewaldi* (Born.), *Mytilus* sp., gastropoda (several species, etc.).
	[10]	16.	Shales, black and greenish-grey, with reddish-brown sandy layers	4	0	
	[9]	17.	Limestone passing into a sandstone: average	0	1	Fish-remains.
	[8]	18.	Marl, yellowish, sandy, laminated	0	5	
	[7]	19.	Limestone, hard, grey, passing into a sandstone of 'bone-bed' nature	0	1	
	[6]	20.	Shale, yellowish, sandy	0	0½	Usual fish-remains; *Protocardia rhætica* (Merian).
		21.	Sandstone	0	4	
		22.	Shale, yellowish, sandy	0	1½	
	[5]	23.	Sandstone, full of vertebrate-remains, passing into a compact limestone	0	4	
	[4]	24 to 26.	Shales, black: about	6	4	
			Sandstone, soft, reddish-brown	0	2	
			Shales, black, clayey: about	1	0	
	[3]	27.	'Wedmore Stone.' Limestone, hard, grey and often blue-centred, shelly, massive: 1 to 3 feet	2	2	*Isocyprina* spp., small gastropoda, and occasional fish-remains.
	[2]	28.	Shales, black, clayey: about	4	0	
KEUPER.	Grey and Tea-green Marls.[4]		Marls and marlstones, whitish and greenish-grey	20	7	
	Red Marls.		Red marls, with zones of grey and mottled marl: seen	20	0	

---

[1] Q. J. G. S. vol. xvii (1861) p. 490; see also 'The Geology of the Country between Wellington & Chard' Mem. Geol. Surv. 1906, pp. 26–27.

[2] Q. J. G. S. vol. xx (1864) p. 403.

[3] These correspond to the numbers of the beds in Prof. Boyd Dawkins's section.

[4] Additional details of these deposits will be found in Prof. Boyd Dawkins's paper.

The limestone called the 'Wedmore Stone' is prominent, and in the past has been extensively worked in the neighbourhood of the country-town whence it derives its name. But now not a single quarry is open, and even traces of former workings are difficult to locate.

The stratigraphical position of the Wedmore Stone has been the subject of discussion. Prof. Boyd Dawkins, in 1864, showed clearly enough that it occurred in the *Pteria-contorta* Shales,[1] although J. H. Blake was dubious about the matter[2]; but in 1887 Mr. H. B. Woodward agreed with Prof. Dawkins that it occurred in the Black Shales.[3] Its true position is about 4 feet above the base of the *Pteria-contorta* Shales, and about 13 below the horizon of the bed that I regard as equivalent to the stratum numbered 15 (or the main Bone-Bed) in other places.[4]

In the neighbourhood of Sand, the Grey and Tea-green Marls are succeeded by 4 feet of 'greenish calcareous shale full of *Avicula* [*Pteria*] *contorta*,' and this by the Wedmore Stone; but the bulk of the deposit between the Wedmore Stone and the Bone-Bed (Bed 15) is a soft ferruginous sandstone.[5]

I have not observed any sections of the Cotham Beds in this inlier, and there are no details available to show how thick they are. Mr. W. A. E. Ussher noticed a bed at West Stoughton, which he thought might represent the Cotham Marble; but, as the Jew Stone, which is the top-stratum in this district of the Langport Beds, is also reputed to resemble Cotham Marble 'in texture and character [although] without dendritic markings,' some care is required in its identification.

The Langport Beds are occasionally exposed at the bottoms of quarries in which the principal strata worked belong to the Lower Lias. The details with regard to the beds about the junction of the Langport Beds with the Lower Lias were all obtained in the neighbourhood of the Stoughtons—a group of villages situated north-west of Wedmore. Four quarries were in work when I visited the neighbourhood for the fourth time, in June 1909. The section in the quarry near the farm, half-a-mile south-west of Ashton Church, is described on p. 55.

The local names of the beds were communicated by one of the quarrymen. In this quarry the Blue-Lias Bed 8 was represented by fragments of limestone in the soil; but it is seen *in situ* at a quarry in a field, on the right-hand side of the road from Ashton to

---

[1] Q. J. G. S. vol. xx (1864) pp. 403 *et seqq.*

[2] 'Geology of East Somerset & the Bristol Coal-Fields' Mem. Geol. Surv. 1876, p. 85.

[3] 'Geology of England & Wales' 2nd ed. (1887) p. 250.

[4] The most satisfactory pieces of Wedmore Stone, from a palæontological standpoint, that I obtained came from a pond-excavation on the north side of the road, 3 furlongs due north of Mudgeley Farm.

[5] The only exposure now available is in the sides of a pond, in the field by the roadside opposite Sand Farm.

Section in the Quarry near Ashton.

		Thickness in feet	inches.	
Lower Lias.	8. Limestone: fragments in soils, but normally	0	8	
	7. 'Broad Shale': hard yellow and blue-grey paper-shales	2	0	
	6. 'Corn Size': fine-textured, blue-centred limestone. Will not stand the frost; 11 to 14 inches	0	11	*Ostrea liassica* Strickl.
	5. Clay	0	1	*Ostrea liassica.*
	4. Limestone, grey, blue-hearted	0	2	(One bed at Stoughton-Cross Quarry, where it contains corals and is 5 inches thick.)
	3. Clay	0	1	
	2. Limestone: locally called 'The Flat'	0	3	
	1. Clay	0	0½	
Langport Beds.	'Jew Stone': hard, compact, yielding a conchoidal fracture	0	7	
	Clay-parting	0	0½	
	Limestone, compact, blue inside, locally called 'The Skud': 4 to 6 inches	0	6	
	Clay-parting	0	0½	
	Limestone: locally called 'The Clog'	0	9	*Protocardia*, *Ostrea* (15 inches thick at Stoughton Cross).

West Stoughton, with the other beds as exposed at the preceding quarry below that stratum. In the quarry at Stoughton Cross the beds are somewhat disturbed; but the sequence is the same as at Ashton, with the modifications noted in parentheses in the record of that section.

(F) The Uphill-Shepton-Mallet Area.

This area embraces those numerous disconnected patches of Rhætic deposits, which are either in actual contact with the Palæozoic rocks of the Mendip Hills, or occur in outliers removed at a greater or less distance therefrom.

In proximity to a mass of older rocks, which—on abundant evidence—formed a land-surface during the time of formation of the newer rocks, it is not to be wondered at that the Rhætic deposits are subject to considerable variation in thickness and character. Some of them are conglomeratic; while sediments of this epoch, along with vertebrate-remains, have found their way into fissures in the Carboniferous Limestone, or repose in shallow hollows upon its much eroded surface. Sometimes, however, where an 'abnormal' development of a Neozoic rock might be expected, there is a 'normal' development instead.

The first section to be noticed is near Uphill, not far from Weston-super-Mare, where the Rhætic Beds are exposed in the great cutting which here traverses the Mendip Hills.

Railway-cutting, Uphill.—This section has been mentioned by several authors. Thomas Wright, Charles Moore, and Bristow & Etheridge, all of them contributed original observations. Mr. H. B. Woodward has given a picture of part of the cutting, showing how highly faulted the beds are; and this feature is still

more clearly brought out in the section made by William Sanders, and reproduced in the Geological Survey Memoir on the district published in 1876.[1]

Wright's description of the section, published in 1860,[2] was closely followed by one drawn up by Moore.[3] Wright's record differs widely from that given later by Bristow & Etheridge,[4] so much so that it is impossible to institute a comparison. These latter do not record a single fossil, and only give details of the *Pteria-contorta* Shales for a distance of 11 feet 9 inches above the top of the marls. Wright's section is not too easy to understand, but he assigns a thickness of a little over 25 feet to the 'Zone of *Avicula contorta*.'

Moore's section, unfortunately, is also of little use, for he gives no details of the deposits between the Lias and the bed which he identified with the Bone-Bed. In his collection at Bath, however, there is a piece of pale yellow limestone, identical as regards lithic structure with the '*Naiadites* Beds' of 'Redland (New Clifton),' Bristol,[5] and containing *Darwinula liassica* (Brodie) and *Lycopodites*, which bears the legend 'Rhætic Plant-Bed, Uphill.' So the Westbury Beds are represented here; and certain of the layers, at all events, are quite typical as regards lithic, faunal, and floral characters respectively.

When I visited the section, by kind permission of the Great Western Railway Company, I found it very much overgrown; but near the top of the western bank, between the single-arch bridge which spans the cutting and Bleadon (or Uphill) Station, I was able to note the following details:—

RAILWAY-CUTTING, UPHILL.

				Thickness in feet	inches.	
LOWER RHÆTIC.	WESTBURY BEDS.	5 *b*.	*Cardium-cloacinum* Limestone. Limestone, hard, dark	2	0	*Placunopsis alpina* Winkler, *Pteria contorta* (Portl.), *Cardium cloacinum* Qu., *Chlamys valoniensis* (Defr.), *Protocardia rhætica* (Merian), *Isocyprina ewaldi* (Bornemann).
			Shales, black	—		
		15.	Bone-Bed *a*. Pyritic sandy limestone, with conspicuous green patches	0	1	*Acrodus minimus* Ag., *Gyrolepis alberti* Ag., *Saurichthys acuminatus* Ag., *Hybodus minor* Ag., small quartz-pebbles, *Isocyprina* sp. indet.
			b. Shale and sandstone-layers	0	3	
			c. Sandstone, hard, grey	0	2	
		16.	Shales, black, laminated; about	3	0	
Non-sequence.						
KEUPER.	Grey & Tea-green Marls.		Marlstone, hard, yellowish-green	1	0	
			Marls and marlstones: according to Bristow & Etheridge, about	37	0	
	Red Marls.					

---

[1] 'Geology of East Somerset, &c.' pl. iii facing p. 24.

[2] Q. J. G. S. vol. xvi (1860) pp. 382–84.

[3] *Ibid.* pp. 445–46.

[4] Vert. Sect. Geol. Surv. 1873, Sheet 46, No. 3.

[5] W. H. Wickes, Proc. Geol. Assoc. vol. xvi (1900) p. 422.

It is unfortunate that so little reliable information is available; but it was interesting to find Bed 5 *b*, which was replete with specimens of *Cardium cloacinum* and *Placunopsis alpina.*

Milton Lane, Wells.—About a mile to the north of Wells is the section that was described by the Rev. P. B. Brodie in 1866 as that of 'Milton Lane.'[1] In it Keuper, Rhætic, and Lower Liassic rocks are exposed, and it is of especial interest in that it shows the last-named in close proximity to the older rocks of the Mendip Hills still maintaining their normal lithic characters.

Two faults, unfortunately, affect the rocks: the one throws the Tea-green Marls against the Red; while the other disturbs the strata which occupy the stratigraphical position of the Cotham Beds, and renders exact details difficult to obtain.

MILTON-LANE SECTION, WELLS.

				Thickness in feet	*inches.*	
LOWER LIAS.			Alternating bands of limestones and shales, of *planorbis, megastomatos,* and *marmoreæ* hemeræ. *Ostrea* Beds and *Pleuromya* Limestones and Shales.			
			[Gap, owing to a slight fault.]			
RHÆTIC.	COTHAM BEDS.	[1.	Position of the Cotham Marble.]			
		2.	Shales pale green and yellow; ? about	3	0	
			Brown arenaceous deposit	0	0½	*Ostrea (?), Natica oppeli* Moore, at the top.
		3.	Limestone, hard, greenish	0	4	
			Limestone, sandy, ferruginous	0	1½	Fish-scales, *Cardium cloacinum* Quenstedt.
			Limestone, hard, greenish-grey	0	4	
			Shale	0	1	
		4.	Marl, greenish-yellow, often indurated	0	9	
	WESTBURY BEDS.	5 *a* to 14.	Shales, black, selenitic, and more clayey at the base: 8 to 9 feet	8	6	Usual *Pteria-contorta*-Zone fossils.
		15.	Sandstone, yellowish	0	1	*Acrodus minimus* Ag. *Gyrolepis alberti* Ag., and small quartz-pebbles.
KEUPER.	TEA-GREEN MARLS.	*a.*	Marlstone, hard, yellow, nodular, with 'beef': 0 to 4 inches	0	4	
		b.	Marl, soft, indurated in places	4	4	
		c.	Marlstone, pale greenish-yellow	1	9	From *b* & *d* Mr. H. B. Woodward records fish-scales.
		d.	Marlstone, soft, whitish: 4 to 8 inches	0	6	
		e.	Marl, dark grey, with occasional nodules at the top	1	4	
		f.	Marlstones with median clay-seam	1	1	
		g.	Marlstone, whitish in dark marl	0	5	
		h.	Marlstone	1	3	
	Red Marls.		Marls, red; seen	2	6	

(Then comes a small fault.)

---

[1] Q. J. G. S. vol. xxii (1866) pp. 93–95.

All the authors who have described this section have noticed a bone-bed at the base of the *Pteria-contorta* Shales; but, while the type that Brodie saw was an ossiferous breccia,[1] and that which Mr. Woodward discovered a 'tough bluish-brown limestone,'[2] that which I found was a yellow sandstone with few vertebrate-remains—a less fossiliferous and thinner Bone-Bed than might have been expected.[3]

Between the outlier on which East Milton is situated and the main mass of Lias near Shepton Mallet, are outliers of Rhætic and Liassic rocks (1) north of Birrel Farm, (2) between the Horringtons, and (3) at Chilcot, but I have nothing to add to what has already been noted.[4]

In the neighbourhood of Shepton Mallet the principal section is that exposed in the railway-cutting south-west of the town, on the line to Wells. Here the Rhætic Beds are fairly well developed, but northwards they thin out, passing into conglomerate, and are eventually overlapped by the Lower Lias, which, when it comes to rest upon the Carboniferous Limestone, passes into a massive sparry limestone, locally called 'Downside Stone.'

Near Downside, this Downside Stone rests directly upon the Carboniferous Limestone; but, a little farther south, near the viaduct, and on the east side of the road, Rhætic beds have come in between the Lias and the well-planed surface of the steeply-dipping Carboniferous Limestone. This section is the classic one that was pictured by De la Beche[5]; but in his time, of course, the Rhætic had not been recognized as a distinct formation, and he called these conglomerate-beds here simply the 'thin gravel base to the Lias.' Charles Moore, however, who was so quick to detect anything Rhætic, soon discovered that this 'thin gravel base' contained vertebrate-remains—such as he knew characterized the Rhætic, so he correlated this conglomerate with that which he had noticed near Hapsford Mills.[6]

This conglomerate at Shepton Mallet is a breccio-conglomerate, consisting of fragments of rocks derived from the Carboniferous Limestone Series (including chert) embedded in a dull-grey matrix in which occur specimens of *Pteria contorta*, vertebræ of *Plesiosaurus*, teeth of *Saurichthys*, *Sargodon*, *Lepidotus*, *Acrodus*, and *Gyrolepis*, scales of *Gyrolepis*, coprolites, small quartz-pebbles, and reptilian bones. The same kind of conglomerate is repeatedly met with in digging graves in the Cemetery, and large pieces of bone are sometimes found embedded in it.

---

[1] Q. J. G. S. vol. xxii (1866) pp. 94–95.

[2] Vert. Sect. Geol. Surv. 1873, Sheet 46, No. 14.

[3] Proc. Geol. Assoc. vol. xxi (1909) p. 225.

[4] 'Geology of East Somerset & the Bristol Coal-Fields' Mem. Geol. Surv. 1876, p. 81.

[5] Mem. Geol. Surv. vol. i (1846) p. 278.

[6] Q. J. G. S. vol. xxiii (1867) p. 507.

About a quarter of a mile due west of the Cemetery is the quarry in the Carboniferous Limestone at Bowlish, in which, adhering to the more or less vertical faces of rock forming the fissure-sides, can often be detected a breccia of Rhætic age containing the small vertebrate-remains characteristic of the epoch; while, resting upon the planed surface of the Carboniferous Limestone (which is here inclined at quite 45°), are the Lower Liassic strata.

On the north side of the combe, about a furlong and a half south-south-west of the above quarry and at the eastern end of Darshill Mill-pond, an adit was being driven at the time of my visit in connexion with a water-supply scheme. The Langport Beds or White Lias proper were full of the ordinary fossils, such as *Volsella minima* (Moore), *Pleuromya crowcombeia* auctt., *Ostrea liassica* Strickl., etc. The uppermost bed was pierced by peculiar annelid-like borings. A few pieces of greyish rock were also found lying about, which were partly conglomeratic like the bed numbered 3 in the Three-Arch-Bridge Railway-cutting (see p. 60).

The section described by De la Beche as situated 'on the south of Croscombe'[1] I have been unable to find, but a mile and a quarter due west of Shepton Mallet Church is an old quarry in the Carboniferous Limestone, on the top of which limestone are traces of littoral 'Tea-green Marl'; while, in the same field, I picked up pieces of a peculiar granular sandy rock containing unmistakable Rhætic fish-remains.

Three-Arch-Bridge railway-cutting, Shepton Mallet. —This, as I have already remarked, is the place where the best exposure of the Rhætic deposits in the district is available, and the cutting is situated about a mile to the west of the town.

The line of demarcation between the Keuper and the Rhætic is sharply defined, and the same remark applies to the upper limit; but, as noticed by Moore, the *Planorbis* Beds are very close down to the Langport Beds, and

> 'on comparing the Liassic beds with the Camel Section, it will be at once apparent that the lower members [of the Lias] are absent. . . .'[2]

As detailed records of this section have been given by Moore, also by H. B. Woodward, W. A. E. Ussher & J. H. Blake,[3] it will only be necessary here to give such details as will permit of its being clearly compared with other sections.

---

[1] Mem. Geol. Surv. vol. i (1846) p. 278.

[2] Q. J. G. S. vol. xxiii (1867) p. 506.

[3] Vert. Sect. Geol. Surv. 1873, Sheet 46, No. 15.

SECTION IN THREE-ARCH BRIDGE RAILWAY-CUTTING.

				Thickness in feet	inches.	
LOWER LIAS.			Limestones and clays: seen about...........................	20	0	
RHÆTIC.	UPPER.	LANGPORT BEDS.	Limestones with marly partings, the whole cream-coloured	12	0	*Chlamys pollux* (D'Orb.). *Plagiostoma valoniense* (Defrance), *Volsella minima* (Moore *non* Sow.), *Protocardia*, etc.
		COTHAM BEDS.	[1. Position of the Cotham Marble.]			
			2. Shales, greenish-grey, marly: 2 to 3 feet	2	6	
			3. Limestone, pale greenish-grey, with arenaceous layers: 12 to 20 inches.	1	4	Fish-scales.
			Thin, hard grey layers, with many quartz-grains and fish-remains, passing down into a hard conglomeratic limestone with small pebbles of Carb. Limestone: 1 to 3 ins....	0	2	*Chlamys valoniensis* (Defr.), coprolites and fish-remains.
			? 4. Shale, pale-green, marly .	0	8	
				4	8	
	LOWER.	WESTBURY BEDS.	5 *a*. Shale, darker, marly	0	11	
			5 *b* to 7 Limestone, grey and black, shaly	0	4	*Chlamys valoniensis*, *Protocardia rhætica* (Merian), *Pteria contorta* (Portl.), *Ichthyosaurus*.
			8 to 14. Shales, black	9	6	
			15. Shale, black, earthy, with nodules and layers of a highly pyritic limestone .	0	7	*Gyrolepis alberti* Ag., *Chlamys valoniensis*.
				11	4	
KEUPER.		TEA-GREEN MARLS.	Marls and marlstones, greenish-grey, corresponding almost bed for bed with those at Milton Lane, Wells	14	3	
		RED MARLS.	Red and variegated marls, with a little celestine and salt-pseudomorphs: seen	12	0	

It should be noticed that Moore doubtfully identified the bed that I have numbered 3 with the 'Flinty Bed' of Beer Crocombe.

South-east of the railway-cutting, past Lamberts Hill, then round the sinuous outcrop of the Rhætic to East Compton, and thence to North Wootton, no sections are available.

The junction of the White Lias proper with the Lower Lias is seen in an interesting section in the tram-line cutting, south of Waterlip Quarry and north-east of Doulting. This section I have described quite recently, and to that description I have nothing to add.[1]

Between the main outcrop of the Rhætic west of Shepton Mallet and the southern end of the Wedmore inlier is broken ground of very diverse stratal composition. Bold and often quarried knolls, partly ringed round with Dolomitic Conglomerate, are inliers of

---

[1] Proc. Geol. Assoc. vol. xxi (1909) pp. 216–17.

Carboniferous Limestone; while hills, varying in size from almost tumulus-like mounds to markedly-conspicuous hills (such as Twine Hill), are composed of Keuper and Rhætic, or Keuper, Rhætic, and Lower Liassic rocks combined.

I have worked over all the outliers in this part, but have found little to add to the already published notes of others.[1]

Twine Hill.—The Lower Liassic beds which cap this hill are precisely similar in appearance to their equivalents at Ashton in the Wedmore inlier (p. 55), comprising limestones and conspicuous beds of shale, in part of *planorbis* hemera. They rest upon the Jew Stone, to which succeed below the more rubbly and fossiliferous limestones of the main mass of Langport Beds.

Lancherley Cross.—Scarcely 200 yards along the road from Lancherley Cross in the direction of Woodford, on the right-hand side, is a small section which affords evidence of the continuation of the main Twine-Hill fault, and suggests that that line of displacement is connected with one of those which traverse the Yarley (or Henton) outlier.

(3) East Somerset (*pars*).

(A) The Nunney-Elm Area.

(i) Introduction.—This area embraces the romantic and picturesque neighbourhood of Nunney and Vallis Vale.

The Nunney Valley has been excavated out of the hard Carboniferous Limestone, which generally has Inferior Oolite resting directly and unconformably upon its well-planed edges. But in places, between the Oolite and the Carboniferous Limestone, are deposits which include Rhætic, Lower Lias, Middle Lias, and Upper Lias. They lie in hollows in the Limestone-surface, or fill in fissures in that rock. The extraordinarily fossiliferous character of these deposits suggests that they represent the accumulations which were, so to speak, washed before the advancing waters.

In Rhætic times there were many fissures in the Carboniferous Limestone of the neighbourhood, and into these fossils of the epoch were washed. In places, however, they were accumulated instead in slight depressions of the limestone-floor, were mixed with angular or rounded fragments, and now appear as conglomerates or breccio-conglomerates fast-fixed to the limestone surfaces.

Farther away from the old sea-margin, where the surface of the Carboniferous Limestone declines, as at Hapsford Mills in Vallis Vale, the Rhætic deposits become less attenuated and gradually lose their conglomeratic facies. About 2 miles to the north-west of Frome, it is recorded that the Bone-Bed, presenting its normal characters, was met with

> 'at a depth of 310 feet, in a pit at present being sunk by James Oxley, Esq., of Frome, to the Lower Series of Coals of the Somersetshire basin.'[2]

---

[1] 'Geology of East Somerset & the Bristol Coal-Fields' Mem. Geol. Surv. 1876, pp. 81–82; see also Q. J. G. S. vol. xx (1864) pp. 403–404.

[2] Geol. Mag. dec. 2, vol. ii (1875) p. 96.

(ii) Stratigraphical Details.

Marston-Road section.—This section, thus named by Moore, is still open, and was visited by the Geologists' Association in 1890 [1] and again in 1909 [2]; but, in the report of the earlier excursion, while there are some remarks on the Inferior Oolite, there are none on the Rhætic.

Charles Moore records that

> 'The Rhætic deposits are represented in the western end of this section by a friable marl, about 10 inches thick, in which occur teeth of *Acrodus*, *Sargodon*, etc., and vertebræ of *Lepidotus*, whilst in the floor of the quarry Carboniferous Limestone is seen.' (Q. J. G. S. vol. xxiii, 1867, p. 482.)

In 1908 a party of the Cotteswold Naturalists' Field Club visited this neighbourhood.[3] The details which I have obtained and recorded below have been checked by both that Club and the Geologists' Association.

MARSTON-ROAD SECTION, HOLWELL.

		Thickness in feet	*inches.*	
INFERIOR OOLITE [4] (*Garantianæ*).	Limestone, hard, dense, conglomeratic at the base ...	2	0	*Acanthothyris spinosa* (Schloth.), *Terebratula (?) globata*, auctt., *Syncyclonema demissum* (Phil.), *Isocardia* sp., *Trigonia* sp. indet., *Ostrea* sp.
	Non-sequence.			
LIAS	Limestone, hard, whitish, sparry, pebbles of pure white limestone (? Langport Beds) at the base. Top portion considerably bored by *Lithophagi*	Variable in thickness.		
	Non-sequence.			
RHÆTIC (Westbury Beds).	Limestone, somewhat sandy and earthy, with fragments of Carboniferous Limestone	0	4	*Acrodus minimus* Ag., *Gyrolepis alberti* Ag., and vertebræ.
	Shale, yellow, gritty, calcareous	0	6	Full of fragments of *Pteria contorta* (Portl.), *Chlamys valoniensis* (Defr.), and *Protocardia*.
	Breccia in intermittent patches, firmly adherent to the Carboniferous Limestone	0	2	Usual fish-remains.
	Unconformity.			
CARBONIFEROUS ...	Carboniferous Limestone, presenting a very irregular surface.			

Leaving this quarry, and descending the hill to Holwell, we notice a quarry on the right just before crossing the brook. This is

---

[1] Proc. Geol. Assoc. vol. xi (1890–91) p. clxxiii. The precise position of the section is where the boundary-line of the Inferior Oolite and Carboniferous Limestone is shown on the Geological Survey map, and immediately below the 'o' in Holwell.

[2] *Ibid.* vol. xxi (1909) p. 220.

[3] Proc. Cotteswold Nat. F. C. vol. xvi (1909) pp. 224–25.

[4] Q. J. G. S. vol. lxiii (1907) p. 399.

the section to which Moore refers in the paragraph on the 'Holwell Carboniferous Limestone & Liassic Dykes,' but except the statement that in one of the dykes 'may be found occasional nests of Rhætic remains,'[1] there is nothing that claims our attention.

Crossing the brook, and ascending the hill on the Shepton-Mallet Road, we come upon an extensive disused quarry, on the left or south side of the road. This is the well-known '*Microlestes* Quarry' of Charles Moore.[2]

From 'dykes' here Moore obtained an extraordinary number of vertebrate-remains, which are now housed in the Bath Museum. Moore intended to devote a special paper to their description, but unfortunately it never appeared. His dyke is localized now with difficulty; but many vertebrate-remains, similar to those collected by him, may still be obtained near its site—including the teeth of the little mammal *Microlestes*.

On the opposite side of the road to the '*Microlestes* Quarry' is an interesting one in the Carboniferous Limestone, in which, however, is a fine 'dyke,' from the sides of which numbers of teeth and scales of Rhætic fishes may be collected. Also, in a hollow excavated out of the surface of the Limestone is White-Lias limestone mixed with pale marl, in which are embedded subangular masses of chert and extremely well-rolled pieces of Carboniferous Limestone, covered with specimens of *Dimyodon intus-striatus* (Emmerich).

Between Holwell and the neighbourhood of Hapsford Mills I have not detected any deposit of Rhætic age between the Carboniferous Limestone and the Inferior Oolite. Near Hapsford Mills, however, there are some extremely interesting sections which were noticed by Charles Moore and later by Mr. J. McMurtrie.[3]

The latter appends a section to his paper, showing the relations of the beds in the three quarries on the east side of the brook at Hapsford Mills. He distinguishes them as A, B, and C,—C being that nearest to the by-road which gives access to the mills and valley from the road to Elm. The quarry farthest away from the by-road is the largest of the three, and according to Mr. McMurtrie was the last to be abandoned. Here at the southern end, as this author states, the Inferior Oolite rests directly upon the Carboniferous Limestone (*loc. cit.*);

> 'but as the eye passes along the face of the quarry to the northward, attention is at once directed to a bed which comes in almost imperceptibly'

between the Limestone and the Oolite.

> 'It consists of a fine conglomerate, occasionally brecciated, but more frequently containing waterworn pebbles, and it shows traces of fish-teeth and scales.' (*Op. cit.* p. 105.)

Masses of the conglomerate above described lie at the foot of the mural quarry-face. The contained pebbles vary greatly in size,

---

[1] Q. J. G. S. vol. xxiii (1867) p. 485.

[2] *Ibid.* p. 487; see also Proc. Geol. Assoc. vol. xxi (1909) p. 221.

[3] Proc. Bath Nat. Hist. & Ant. F. C. vol. v (1885) p. 104.

are well-rolled, and frequently very much bored by a species of *Polydora*.[1]

The pebbles are cemented together by a dull-grey matrix, in which occur specimens of *Plagiostoma valoniense* (Defr.), *Dimyodon intus-striatus* (Emmerich), *Pteria contorta* (Portl.), *Chlamys valoniensis* (Defr.), *Ostrea fimbriata* Moore (some of which are bored by *Polydora*), *Cardium* sp., *Cardinia* sp., *Plicatula (?) hettangiensis* Terquem, *Pollicipes rhæticus* Moore, echinoid radioles, *Gyrolepis alberti* Ag., fragments of saurian bones, etc.

It was Charles Moore, however, who described the sections here in greatest detail; and probably, but for regrettable causes, there would have been yet more detailed information available.

He gives records of two of the sections at the Hapsford-Mills end of Vallis Vale. The first and southern one of the two was measured at, or near, the northern end of what is called by Mr. McMurtrie Quarry 'A.'

SECTION IN VALLIS VALE.

		Thickness in feet	*inches.*	
INFERIOR OOLITE.	Limestone, with basal conglomerate containing Carboniferous Limestone corals (derived): seen	12	0	
	Non-sequence.			
RHÆTIC (Cotham & Westbury Beds).	Clay with limestone-bands and nodules	1	0	*Estheria minuta*, var. *brodieana* Jones, *Lycopodites lanceolatus* (Brodie), insects.
	Conglomerate	0	4	*Estheria minuta*, var. *brodieana*, *Protocardia (?)*.
	Clay, blue	0	4	
	Conglomerate	2	0	Fish-scales and teeth.
	Clay, blue	0	4	*Pteria contorta* (Portl.), *Chlamys valoniensis* (Defr.), *Chiton rhæticus* Moore, *Pollicipes rhæticus* Moore, fish-scales.
	Unconformity.			
CARBONIFEROUS.	Limestone: seen about	15	0	Dip, 35° N.W.

The foregoing details are derived (but have been checked) from Moore's observations recorded in the Quarterly Journal of this Society for 1861, vol. xvii, p. 497, and in Prof. T. Rupert Jones's 'Monograph of the Fossil *Estheriæ*'[2]: for Moore sent specimens of *Estheria* to Prof. Jones for identification and notice in his Monograph, along with stratigraphical details.

Section at Hapsford Mills.—The last section to be noticed in this area is in the quarry which has been partly utilized for a saw-pit, just before turning into the by-lane leading to the Elm road.

---

[1] F. A. Bather, Geol. Mag. dec. 5, vol. vi (1909) p. 109; and *ibid.* vol. vii (1910) p. 114.

[2] Palæont. Soc. 1862, pp. 73–74.

SECTION AT HAPSFORD MILLS.

		Thickness in feet	inches.	
INFERIOR OOLITE.	1. Limestone, rubbly, about	3	0	*Ctenostreon pectiniforme* (Schloth.), *Trichites*, *Acanthothyris spinosa* (Schloth.).
	Non-sequence.			
LANGPORT BEDS.	2. Limestones, white. The top-bed is well bored. The borings may be discerned from the floor of the quarry.	2	6	
COTHAM BEDS.	3. Conglomerate: according to Moore	2	0	*Lycopodites lanceolatus* (Brodie), fish-scales. In the Moore Collection at Bath there is a specimen of a pupa-case embedded in rock from about this horizon.[1]
	4. Limestones, marly, often conglomeratic, harder at the base, with shelly layers	3	0	
	5. Marls, black and brown, white-banded	3	0	
WESTBURY BEDS.	6. Clay, blue, with pebbles 7. Conglomerate 8. Conglomerate 9. Clay, blue 10. Conglomerate	2	9	
	11. Clay, blue	0	2	
	12. Conglomerate, 8 to 14 inches	0	10	*Acrodus minimus* Ag., *Gyrolepis alberti* Ag., and a number of minute teeth obtained by washing.
	13. Clay, tough, bluish	0	2	
	14. Conglomerate and clay, 0 to 4 inches	0	2	
	Unconformity.			
CARBONIFEROUS.	Limestone. Highly inclined, but with a well-planed top.			

From fallen blocks of conglomerate Moore obtained *Pteria contorta* (Portl.), *Dimyodon intus-striatus* (Emmerich), *Orbiculoidea? townshendi* (Forbes), and *Ostrea fimbriata* Moore. Moore was of opinion that these conglomerates had formed slowly, and the condition of the shells, vertebrate-remains, and pebbles certainly supports this view.

My record differs little from Moore's.[2] He failed to find *Estheriæ* or plant-remains in Bed 4.[3] In some pieces of the rock, however, remains of lycopods are not uncommon,[4] and it is interesting to note that this is the farthest place south at which they have been found up till now (1910). Moore also expressed some doubt as to the white limestones being 'White Lias'; but he need not have done so, for they are quite typical. The uppermost stratum of the Langport Beds is noticeably bored and waterworn.

(B) The Radstock Area.

Nowhere in this part of East Somerset are the Rhætic deposits very thick, and at Upper Vobster all that represents them is an occasional thin stratum, with fish-scales, etc. adhering to the surface of the Carboniferous Limestone.[5]

---

[1] Mr. W. H. Wickes has a similar specimen of 'a pupa-case of a dragon-fly' from the '*Naiadites* Bed' of 'Redland (New Clifton), Bristol.'

[2] Q. J. G. S. vol. xxiii (1867) pp. 490–491.

[3] *Ibid.* p. 491.

[4] Proc. Cotteswold Nat. F. C. vol. xvi (1909) p. 226; and Proc. Geol. Assoc. vol. xxi (1909) p. 223.

[5] Proc. Geol. Assoc. vol. xxi (1909) p. 222.

The principal section in the Radstock district is that which is exposed in the railway-cutting at Chilcompton. It has been very briefly noticed by Mr. H. B. Woodward.[1]

SECTION IN CHILCOMPTON RAILWAY-CUTTING.

				Thickness in feet	*inches.*	
RHÆTIC.	LANGPORT BEDS.		Limestones, rubbly, white, mixed with marl and clay: seen	2	0	
			Limestone	0	2	
			Marly clay or rubble	0	3	
			Limestone, usually in three beds	0	8	
				3	1 seen.	
			Clay, tough, black and brownish.	0	5	
	COTHAM BEDS.	1.	Cotham Marble. Typical arborescent form, mammillated top: 5 to 9 inches	0	7	
		2.	Marls, pale greenish-yellow, darker in places, especially at the base	2	6	
		3.	Limestone, pale-yellow and bluish, argillaceous and very conspicuous, with a thin, greyish-green, rather gritty layer above it, containing fish-remains: 0 to 8 inches	0	4	
		4.	Shales, marly, passing down into	1	0	
				4	10	
	WESTBURY BEDS.	5 *a*.	Shales, black, marly	2	0	*Isocyprina ? ewaldi* (Bornemann), *Protocardia rhætica* (Merian).
		5 *b*	Sandstone in thin layers, with clay-partings	0	2	
		6.	Shales, black	1	0	
		7.	Limestone, grey, micaceous, arenaceous in several layers with clay-partings; conspicuous	0	3	*Isocyprina ewaldi, Chlamys valoniensis* (Defr.).
		? 8 to 14.	Shales, black, thinly-laminated.	2	0	
			Shales, black, non-laminated	1	0	
		15.	Bone-Bed. Greenish earthy limestone, crowded with the usual fish-remains, and containing a few derived fragments of Tea-green Marl; quartz-pebbles: $\frac{1}{4}$ to $2\frac{3}{4}$ inches.	0	1	*Saurichthys acuminatus* Ag., *Sargodon tomicus* Plien., *Gyrolepis alberti* Ag., *Acrodus minimus* Ag., fish-vertebræ, and coprolites.
			Non-sequence.	6	6	
KEUPER.	TEA-GREEN MARLS.		Marl, soft, greenish: 4 to 8 inches	0	6	
			Marlstone, earthy, greenish-grey, conspicuous: 2 to 6 inches	0	4	
			Marls and earthy marlstones	3	0	
			Marlstone, earthy: 3 to 7 inches	0	5	
			Marls, soft, bluish-green: about	8	0	
	RED MARLS.		Marls, red.	12	3	

---

[1] 'Geology of East Somerset & the Bristol Coal-Fields' Mem. Geol. Surv. 1876, p. 79.

The *Pteria-contorta* Shales are very thin here, and the feeble development of the usually-associated hard beds is at once noticeable. There are no Sully Beds, but the Bone-Bed is particularly rich in vertebrate remains, and reminds the observer very forcibly of the 'thin' portion of the Lilliput Bone-Bed (Chipping Sodbury).

The Westbury Beds are represented, and are easily separable from the Langport Beds—the Cotham Marble being typically developed and readily accessible. Mr. Woodward recorded its occurrence here, but was unable to detect it *in situ.* The bed, however, is in its usual position, and has the peculiarly tough clay-bed immediately above. Except for the intervention of two more or less regular limestone-beds, the rubbly deposits of the Langport Beds—crowded with fossils—follow at once. Rubbly and more fossiliferous limestones usually occur in the lower portion of the Langport Beds in East Somerset north of the Mendip Hills, and in South Gloucestershire.

There are no sections of the Rhætic in the neighbourhood of Kilmersdon, other than those of the uppermost strata of the Langport Beds in the Lias quarries.

Foxcote railway-cutting.—In the railway-cutting north of Foxcote, some 3 miles up the line from Radstock in the direction of Bath, the Rhætic was formerly exposed, and Mr. H. B. Woodward assigned a thickness of about 6½ feet to the Tea-green Marls and 12 feet to the *Pteria-contorta* Shales (*op. cit.* p. 77).

The Rhætic Bone-Bed, pyritic and full of fish-remains, was passed through in the sinking of the Dunkerton-Colliery shaft, near Comerton, and certain of the beds were also displayed in the railway-cutting immediately to the west.

SECTION IN THE RAILWAY-CUTTING AT DUNKERTON COLLIERY.

			Thickness in feet	*inches.*	
COTHAM BEDS.	1.	Cotham Marble. Typical development. (Pieces on the bank, but not *in situ.*)	0	7	
	2 to 4.	Marls, pale greenish-yellow	—	—	?
WESTBURY BEDS.		Shales, black: seen 2 or 3 feet	2	6	*Pteria contorta* (Portl.).
		Sandstones and shales, brown, micaceous, with clayey shale-partings	0	10	Fish-remains.
		Shales, black, laminated	1	8	
		Shale, black, clayey	0	6	*Acrodus minimus* Ag., *Gyrolepis alberti* Ag., *Saurichthys acuminatus* Ag.
		Bone-Bed. Soft grit: 0 to 2 inches	0	1	
~~		Non-sequence.			
TEA-GREEN MARLS.	1.	Clay, greenish, marly	0	10	
	2.	Clay, brown, marly	0	10	
	3 to 5.	Two beds of hard, greenish-yellow, blue-centred marlstone	—	—	?
	6.	Marls, brownish and greenish	10	4	
RED MARLS.		Marls, red	—	—	?

Mr. H. B. Woodward has briefly noticed this section.[1]

---

[1] 'Summary of Progress for 1907' Mem. Geol. Surv. 1908, pp. 155–56.

(C) The Stone-Easton Outlier.

Where the Rhætic impinges on the Palæozoic rocks, its deposits frequently become conglomeratic, and in this neighbourhood sandstones are more in evidence than usual.

The principal sections in the district now open are at the Emborough Fullers'-Earth Works. They have been described by Prof. C. Lloyd Morgan & Prof. S. H. Reynolds[1]; but, as one of the primary objects of this paper is to bring the various sections into line, it is impossible to avoid some amount of recapitulation.

Referring to the sketch-map given by these authors, in exposures 9 & 10 the Tea-green Marls, which are worked for Fullers' Earth, are seen overlain by sandstone. The bottom-portion of this sandstone, which is conglomeratic and contains fish-scales, rests, according to Prof. Lloyd Morgan & Prof. Reynolds, upon an eroded surface of the Tea-green Marls. Section 12 of these authors affords the best exposition of the beds: in it the top-bed is a sandstone, of which a thickness of 2½ feet is visible. This sandstone-bed floors the contiguous section, where it is overlain by 3 feet of compact pale or mottled clay: this is doubtless on the horizon of Beds 2 to 4 of the Chilcompton section. Prof. Lloyd Morgan & Prof. Reynolds did not notice any Cotham Marble; but it occurs in the outlier and should come, of course, between the 'compact or mottled clay' and the Langport Beds or White Lias proper.

SEQUENCE AT THE EMBOROUGH FULLERS'-EARTH WORKS.

					Thickness in feet	*inches.*	
RHÆTIC.	UPPER.	LANGPORT BEDS.		(In pieces on the surface of the fields.)			
		COTHAM BEDS.		[? Clay, tough, black	0	5	
			1.	Cotham Marble	0	7]	
				(In Section 12 of Lloyd Morgan & Reynolds.)			
			2 to 4.	Marl, greenish-yellow: seen 3 feet?	3	10	
					4	10	
	LOWER.	WESTBURY BEDS.	5 *a* & *b*.	Sandstone, grey, micaceous. (In Section 12 of Ll. M. & R.) Sandstone: estimate	4	0	*Isocyprina ewaldi* (Born.), *Pteria contorta* (Portl.), *Pleuromya* sp.
			6.	Shale, pale-grey, marly	0	8	
			7.	Sandstone, with layer of 'beef' on the top	0	3	Usual vertebrate-remains.
			8.	Shales, black, weathering grey.	1	8	
			9.	Sandstone, yellowish-brown: 0 to 1 inch	0	0½	
			10.	Shale, black: average	0	8	
			11.	Sandstone	0	0½	
			12.	Shales, black	1	0	
			13.	Sandstone, laminated sometimes, at others conglomeratic, containing small pebbles of Carboniferous Limestone.	0	5	Crowded with the usual vertebrate-remains, notably *Sphærodus* and *Lepidotus*.
			14.	Sandstone, false-bedded	1	5	
			15.	The Bone-Bed—The coarse conglomeratic base to Bed 14	0	5	Usual vertebrate-remains.
					10	7	
KEUPER.				Tea-green Marls	10	0	
				Red Marls.			

---

[1] Proc. Bristol Nat. Soc. ser. 3, vol. ix (1899–1901) pp. 109–17.

The section in the road-cutting near Old Down Inn is quite overgrown; but portions of that in the railway-cutting, which has been described by the Rev. H. H. Winwood[1] and by Mr. H. B. Woodward,[2] are still visible.

(D) The Hinton-Blewet Area.

In this 'outlier' the Tea-green Marls are about 11 feet thick, and the *Pteria-contorta* Shales about 10 feet.

In the lane leading from Hinton-Blewet to Shortwood Common, the Cotham Marble and other deposits composing the Cotham Beds can be seen, together with the underlying black shales and associated limestones and sandstones composing the Westbury Beds, and then the Tea-green and Red Marls; but the best exposure of the *Pteria-contorta* Shales in the outlier is in the steep bank on the west side of the lane that leads from the Cross Roads on Burledge Hill to Bishop's Sutton. Here was discovered a fine development of the Cotham Marble, and a limestone-bed comparable with the *Pecten*-Limestone of Chilcompton, only in places pyritic and full of fish-remains.

(E) The Harptree Area.

At Harptree Hill, Triassic, Rhætic, and Liassic deposits occur in a hollow that was excavated out of Old Red Sandstone and Carboniferous Limestone. The Old Red no doubt furnished the arenaceous material of which the Rhætic deposits are here mainly composed, and most likely percolating waters with silica in solution have brought about the partial silification of the superincumbent Liassic deposits.

These abnormal facies of the Rhætic and Liassic strata here occasioned considerable difficulty in their early correlation. Thus Thomas Weaver regarded them as being of the same age as the Blackdown Beds (Selbornian)[3]; Buckland & Conybeare thought them possibly comparable with the Dolomitic Conglomerate (Keuper)[4]; but De la Beche detected their partial Liassic age,[5] and Mr. H. B. Woodward separated them as Rhætic and Liassic.[6]

There is only one section open now (1905), and that is the celebrated 'pot' or 'swallet-hole,' about half-way between East Harptree and the Castle of Comfort.

> 'It is about 60 feet in diameter at the mouth, is funnel-shaped, and about 20 to 30 feet in depth. It is evidently a natural "pot" or "swallet-hole." The section consists almost entirely of massive bedded chert, occurring in layers of from 1 to 3 feet in thickness, standing out sharply, but sometimes weathering sandy at the exterior, and separated by thin clayey beds an inch or two in thickness. The beds are coated here and there with quartz crystals.'[7]

---

[1] Proc. Bath Nat. Hist. & Ant. F. C. vol. iii (1874–77) pp. 300–304.

[2] 'Geology of East Somerset & the Bristol Coal-Fields' Mem. Geol. Surv. 1876, p. 79 & pl. iv.

[3] Trans. Geol. Soc. ser. 2, vol. i (1824) p. 365.

[4] *Ibid.* p. 294.

[5] Mem. Geol. Surv. vol. i (1846) p. 277.

[6] 'Geology of East Somerset & the Bristol Coal-Fields' Mem. Geol. Surv. 1876, p. 105; see also p. 108.

[7] 'The Jurassic Rocks of England: the Lias of England & Wales' vol. iii (1893) p. 124.

The higher beds are of *megastomatos* hemera,[1] and I collected from them *Radula pectinoides* (Sowerby), *Myoconcha psilonoti* Quenstedt, and *Caloceras* cf. *johnstoni* (Sow.).

The precise junction of the Lower Lias with the Rhætic cannot be determined, as there are no sections now open; but, below the cherty beds, 'near the cottage at Harptree Hill,' Mr. H. B. Woodward observed 'hardened reddish-brown micaceous sand with *Pullastra arenicola*,' and in the same neighbourhood he also obtained *Pteria contorta* and *Chlamys valoniensis*.

Even the Keuper is cherty, as can be readily seen in the old quarry near Eastwood House, East Harptree; and thus it is evident that the influence of the Old Red Sandstone of the North and Egar Hills has made itself extensively felt.

(F) The Nempnet Outliers.

(i) Introduction.—The Nempnet outliers are situated between the Carboniferous-Limestone masses of Broadfield Down and the Mendip Hills, which are here only some 3 miles apart.

The red marls in the Vale of Wrington show frequent evidence of the proximity of the Palæozoic rocks, in the shape of massive conglomerates, intercalated sandstones, and derived fragments of Carboniferous rocks. The Lias, which reposes in hollows in the Carboniferous Limestone of Broadfield Down, is also frequently conglomeratic, and the mass partakes of the nature of the Sutton Stone of Glamorganshire. On Harptree Hill, in the Mendips again, as already mentioned, are peculiarly-cherty Liassic beds; and so it is not surprising to find that, in the intervening area, on the Nempnet Hills, conglomerates of Rhætic age occur.

The Red Marls with their associated sandstones, and bands of greenish-grey marl in their upper portion, are succeeded by the Keuper Tea-green Marls, and these in turn by the *Pteria-contorta* Shales. Lack of sections prevented me from ascertaining whether there was any Bone-Bed present, or the nature of the Cotham Beds; but the Langport Beds are typically developed, and exposed in numerous quarries. There are no Watchet Beds, and the *Pleuromya*-Limestones of the Lower Lias follow the Langport Beds at once.

The interesting feature of the outliers, at least of the Nempnet-Butcombe outlier, is the occurrence of massive conglomerates, which in places extend upwards—certainly from within a very short distance of the top of the Tea-green Marls—into the Langport Beds, if not higher, replacing, where they occur, the greater part of the *Pteria-contorta* Shales, the Cotham Beds, as well as the Langport Beds. The 'Butcombe Conglomerates,' as these clastic accumulations may be termed, are well exposed at Cuckoo's Nest (half-way between Butcombe and Nempnet) and near Butcombe Church. The part exposed at the former place largely replaces the *Pteria-contorta* Shales, as it contains fragments of vertebrate-remains, *Chlamys valoniensis* (Defrance), and *Pteria contorta* (Portlock).

For the convenience of the future student, the details which I

---

[1] 'Geology in the Field' (Jubilee vol. Geol. Assoc.) pt. ii, 1910, p. 336.

obtained may be given in the order in which they would be noted if a walk were taken from Chew Stoke over Breach Hill, past Nempnet and Butcombe Church, to near Pigeon House, and thence back again by way of Butcombe and Nempnet Farm, West Stroud, and Grubble and Pear-Tree Hills.

Brief remarks on the beds under consideration in the Nempnet outliers are contained in the Geological Survey Memoir on East Somerset (1876, pp. 79–80).

(ii) Stratigraphical Details.

Breach-Hill outlier.—This hill is capped with Lower Lias. At the hamlet is a quarry showing the *Pleuromya* Beds resting upon the Sun-Bed of the White Lias proper. In the steep bank above the road leading off the hill in the direction of Chew Stoke, pieces of a *Pecten* Limestone (containing, with the characteristic lamellibranch *Pteromya crowcombeia* Moore, *Placunopsis alpina* and *Gyrolepis alberti*) and of a yellow sandstone, an inch thick, were found; while below are traces of the Tea-green Marls and a fine section of the Red Marls. Similar beds are seen in the lane leading down the western flank of the hill to Dewdown Farm.

Nempnet-Butcombe outlier.—A succession similar to that seen in the above-mentioned lane is to be observed in ascending the hill opposite: the Tea-green Marls being apparently but 6 feet thick, and the *Pteria-contorta* Shales only 8 feet. The Langport Beds are exposed in a quarry in the field on the right, where the *Pleuromya*- and *Ostrea*-Beds are seen above them.

At Cuckoo's Nest the conglomerates for which that locality is notable are excellently exposed. In descending the lane, the succession is noted as follows:—

			Ft.	*ins.*
WEST-BURY BEDS.	Butcombe Conglomerate.	Conglomerate, composed of pebbles of Carboniferous Limestone embedded in a matrix of shell-débris and calcite, through which are sparsely distributed fish-scales and teeth, coprolites, and fragments of bone. The shell-fragments are best seen on a weathered surface, and are of *Chlamys valoniensis, Isocyprina*, etc.		
		Limestone, rarely conglomeratic, containing not infrequently the usual Rhætic fossils	0	3
		Shales, black; comparatively thin.		
TEA-GREEN MARLS.		Marls, greenish.		

Between Cuckoo's Nest and Nempnet Farm is a large quarry in the *Johnstoni*-, *Ostrea*-, and *Pleuromya*-Beds, with the Sun-Bed and immediately-underlying 'Cockle-Bed' at the base. This Cockle-Bed is a peculiar, cavernous White-Lias limestone.

In the steep bank north-east of Butcombe Church the Butcombe Conglomerate must be at least 8 feet thick, and contains some very big pebbles of Carboniferous Limestone.

Pigeon-House outlier.—In this outlier the *Pteria-contorta* Shales are exposed at several places in the lane running along the northern side; and in a watercourse, under the 'o' of House in 'Pigeon House' on the Geological Survey map, Sheet xix, I found a *Pecten* Limestone.

Grubble-Hill outlier.—Portions of the Red Marls, Tea-green Marls, *Pteria-contorta* Shales (with a *Pecten* Limestone, 1 to 3 inches thick, and *Volsella* sp. indet., *Saurichthys* [tooth], and fish-scales), and the pale marls of the Cotham Beds are to be observed in the sides of the lane which climbs the western flank of the outlier; while in a quarry at the eastern end are seen about 4 feet of Langport Beds overlain by certain Lower Liassic deposits, which correspond—so far as the upward succession goes—bed for bed with the equivalent rocks in the quarries on Breach Hill, and between Cuckoo's Nest and Nempnet Farm.

Banwell outlier.—There are no exposures of the Rhætic on this outlier, but the *Planorbis* Beds are finely displayed in a quarry near Knightcote.

EXPLANATION OF PLATES I–IV.

Plate I.

View of Blue Anchor Point, showing the anticlinal arrangement of the deposits.

Plate II.

Foreshore section near the first gypsum-workings, Blue Anchor Point.

Plate III.

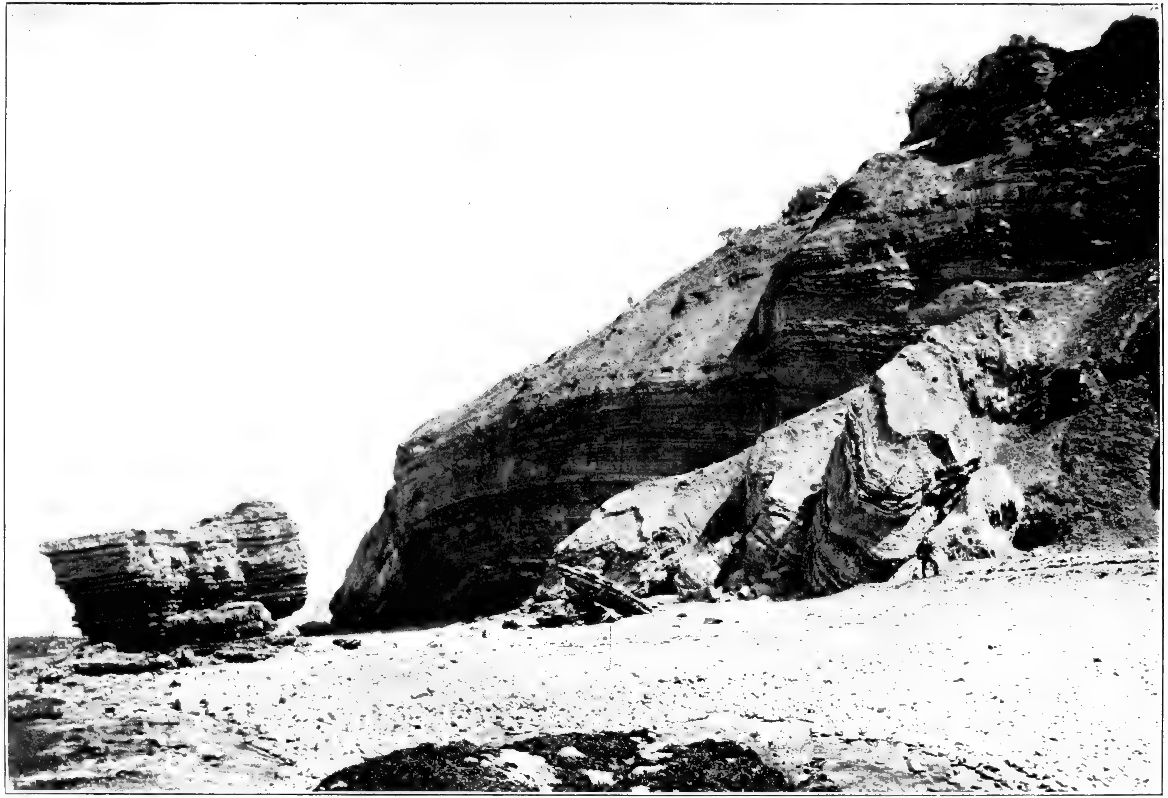
Fig. 1. The upper part of the cliff at Blue Anchor Point.
2. The lower part of the cliff at the same locality.

Plate IV.

The Warren-Farm section: Upper Keuper Marls.

Discussion.

Mr. S. S. Stanley said he thought that the point to be decided was whether the Sully Beds were conformable to the superimposed Rhætic strata or to the Upper Keuper below them. So far as his own observations went in the Southam, Ufton, Harbury, and Chesterton parishes, where the beds occurred at the surface, and also in the Stratford-on-Avon vicinity, they were conformable to the Rhætic. With regard to the Stratford neighbourhood, the speaker thought that there the beds showed an estuarine origin, as fossil insects were fairly abundant. Neither the late Rev. P. B. Brodie nor he himself had ever found anything like an insect in the Harbury neighbourhood; and so it might perhaps be inferred that there the beds were deposited at a greater distance from any coast. Between Harbury and Whitnash, on the Roman Fosse Road, two or three very interesting faults were noticeable. In no case could the Sully Beds be found conformable to the New Red Sandstone, so far as the knowledge of the speaker went. The localities to which he referred were about 4 miles from Leamington. The cutting on the Great Western Railway, as that line approached Harbury from Leamington, commenced on the west in the New Red Series, and passed through the Rhætic into the Lower Lias: the contour and the dip made almost a right angle.



L. R. photogr.

VIEW OF BLUE ANCHOR POINT, SHOWING THE ANTICLINAL ARRANGEMENT OF THE DEPOSITS.

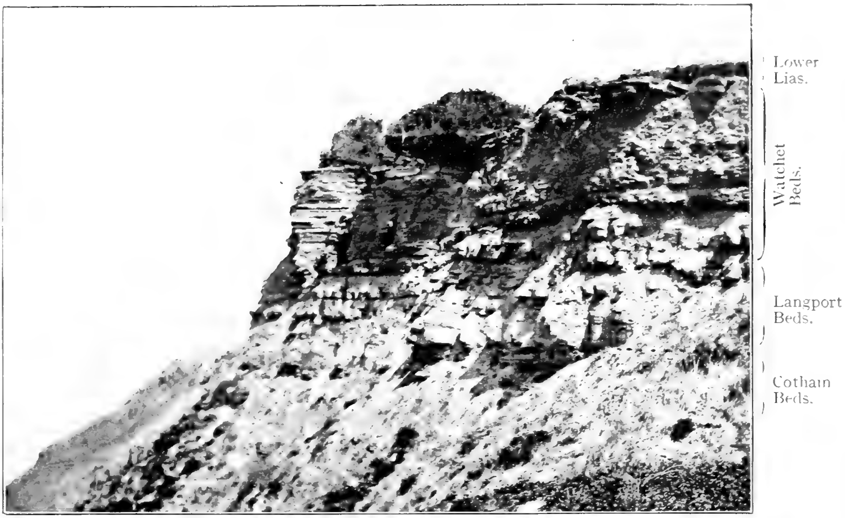
L. R. photogr.

FORESHORE SECTION NEAR THE FIRST GYPSUM-WORKINGS.

[This is the most satisfactory section in the Watchet area for collecting fossils: some of the beds are numbered].

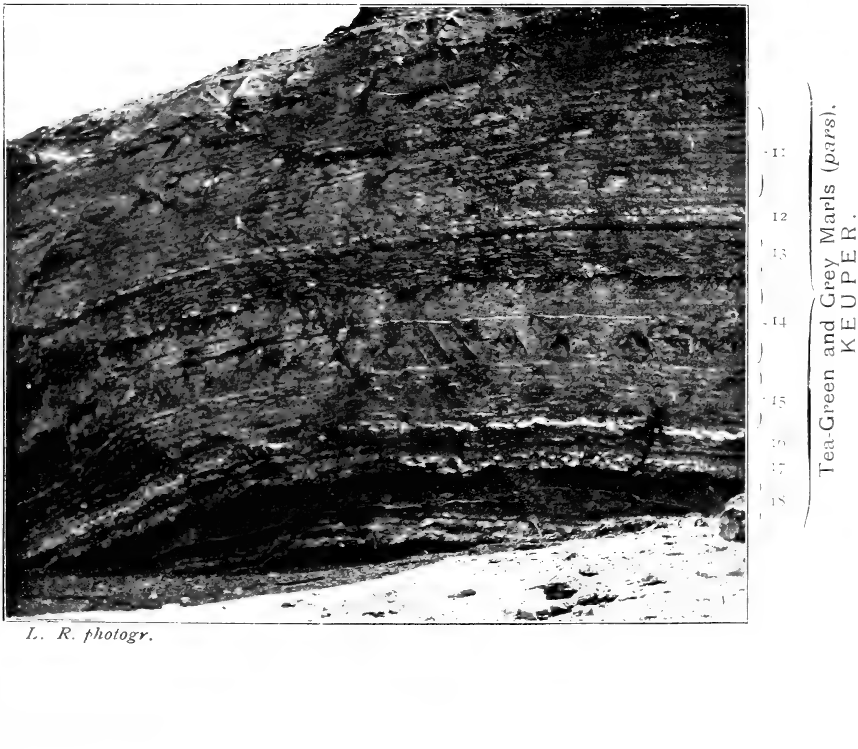
Quart. Journ. Geol. Soc. Vol. LXVII, Pl. III.

Fig. 1.—THE UPPER PART OF THE CLIFF AT BLUE ANCHOR POINT.

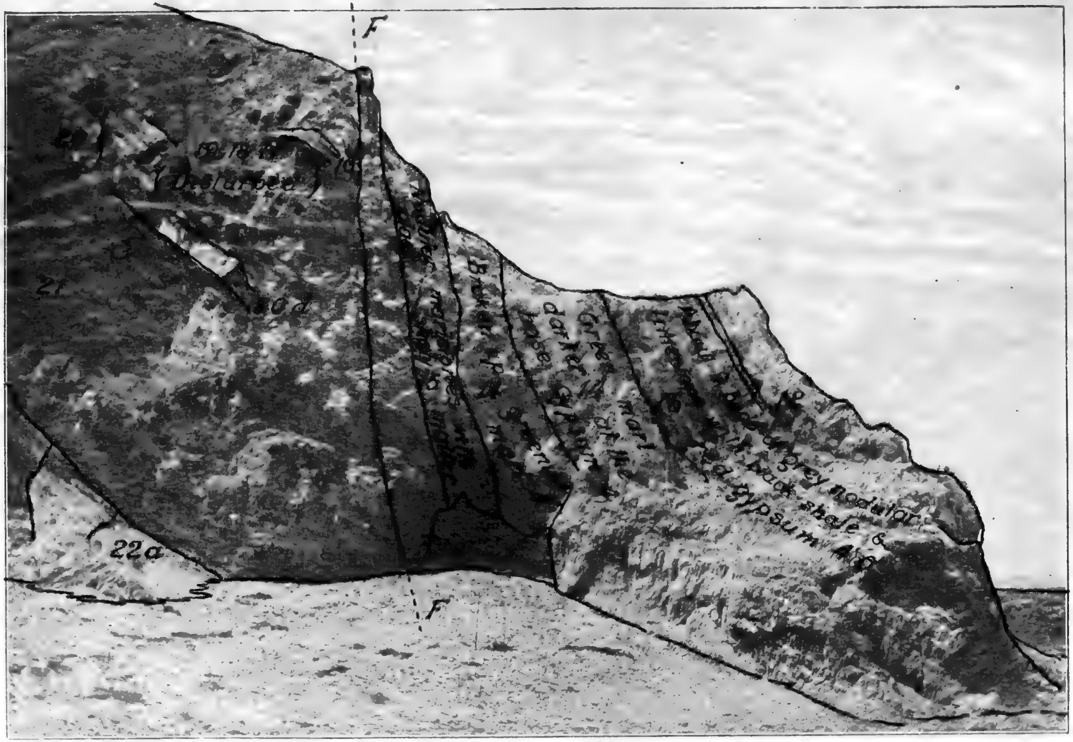


L. R. photogr.

Fig 2.—THE LOWER PART OF THE CLIFF AT BLUE ANCHOR POINT.
[Keuper Marls with veins of gypsum.]

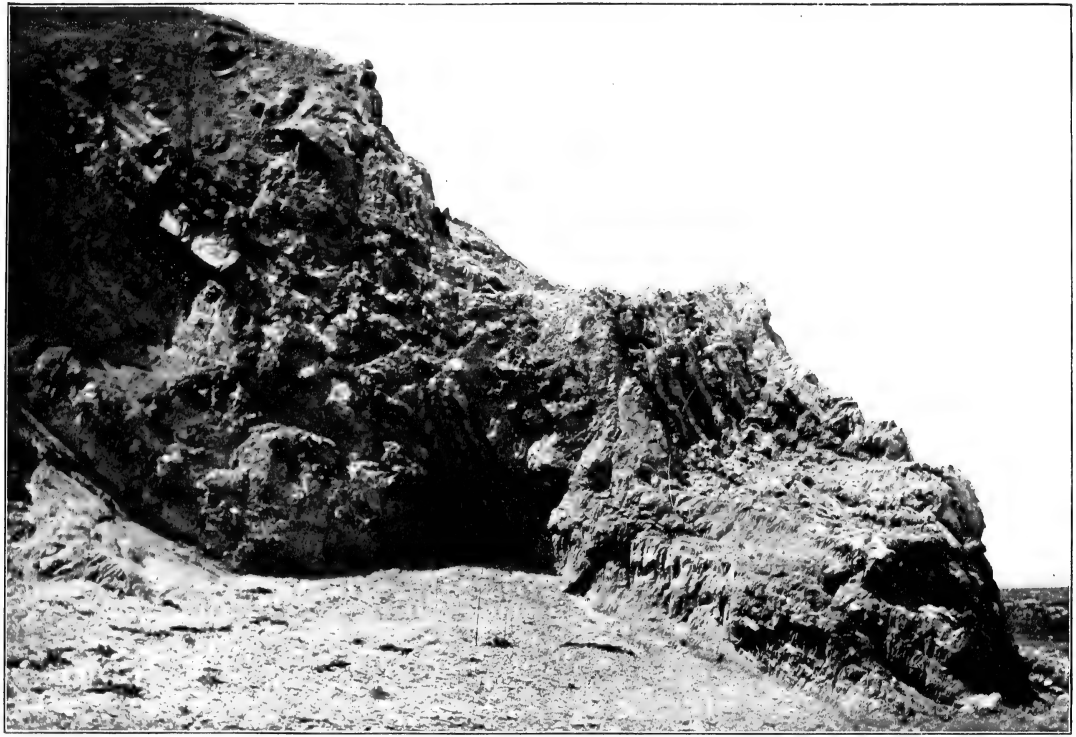


L. R. photogr.



L. R. photogr.

WARREN FARM SECTION. [Upper Keuper Marls].



L. R. photogr.

WARREN FARM SECTION. [Upper Keuper Marls].

Dr. J. E. Marr expressed the desire that names ending in 'ian'[1] should, so far as possible, be confined to those larger divisions which in the nomenclature of the International Geological Congress were called 'series.' As a teacher, he would suggest that less confusion would be introduced if the Author adopted the term 'Rhætian' for what he called 'Rhætic,' and used the terms 'Somerset Beds' and 'Lilstock-Sully Beds' for what appeared as 'Somersetian' and 'Rhætian' in his stratigraphical table. Each of the two last-named divisions included only about 60 feet of rock, and they were, therefore, hardly 'series' in the accepted sense of that term.

Dr. Strahan, while expressing his sense of the value of the Author's highly detailed examination of Rhætic sections, still found himself unable to accept the definition of the Rhætic base given in this paper. Previously to the re-survey of South Wales the Tea-green Marls had been included in the Rhætic. They passed, however, so imperceptibly down into the underlying Red Marls, that it was obviously impossible to separate them with precision. On the other hand, there existed between these green beds and the overlying Black Shales a well-marked plane of separation which was recognizable over a large area in England and Wales. No fossils, beyond some remains of fishes and an oyster, were known to occur below this plane in South Wales, whereas a Rhætic fauna abounded above it—facts which, taken in conjunction with the occurrence of a conglomeratic Bone-Bed resting on the plane, indicated a sudden invasion of the sea. Subsequently to the re-survey the Author recorded Rhætic fossils from below this plane, the account of their occurrence, however, being such as to leave him (the speaker) under the impression that they had been found on the top of the green beds, not in them. If, as the Author now again maintained, they occurred in the green beds, the fact would be interesting as showing that a prevalence of estuarine conditions enabled some of the Rhætic molluscs to enter the region before the general incursion of the Rhætic fauna. How nice was the balance between estuarine and open-sea conditions was indicated by a temporary recurrence of sediments of Keuper-Marl type in the Upper Rhætic. The appearance, however, in the green beds of a few forerunners of the Rhætic fauna did not convince the speaker that a well-marked stratigraphical and palæontological horizon should be abandoned in

---

[1] [The following was the classification suggested, with the exception of two alterations: the replacement of the term Westbury Beds by Cotham Beds (III), and that of Lilstock Beds by Westbury Beds (IV):—

LIAS.	Hettangian.	*Ostrea* Beds, etc.
RHÆTIC.	Somersetian.	I. Watchet Beds ('Marly Beds of the White Lias').
		II. Langport Beds (White Lias proper).
		III. Cotham Beds (Upper Rhætic).
	Rhætian.	IV. Westbury Beds (Black Shales).
		V. Sully Beds (Fossiliferous Grey Marls).
KEUPER.	Keuperian.	Tea-green and Grey Marls. Red Marls.

L. R., February 16th, 1911.]

favour of one which was wholly indefinite, as the base of the Rhætic group.

The PRESIDENT (Prof. WATTS) expressed his sense of the importance of the Author's work and of the interest of the non-sequences revealed by a close study of the Jurassic and Rhætic zones. In the matter of mapping, he thought that it would always be necessary to carry on the practice of field-mapping by means of physical characters, the true position of the beds being checked by palæontological evidence.

The AUTHOR, in reply, said that more field-work was necessary before the precise horizon at which insect-remains occurred could be indicated. Referring to Mr. Stanley's remarks, he was not aware of any facts to suggest that there was a non-sequence between the Red Marls and the Tea-green Marls in Warwickshire; but he did hold that there was a gap between the latter and the Black Shales—he thought that the Sully Beds and the bottom portion of the Black-Shale subdivision were wanting.

With regard to Aust Cliff, the Author held that the Sully Beds and practically the whole of the infra-Bone-Bed deposits were absent, and those who knew from personal investigation the ordinary phenomena associated with non-sequences would appreciate the significance of rolled masses of Tea-green Marl embedded in the Bone-Bed there.

In reply to a question put by Mr. Monckton, the Author remarked that most Rhætic field-geologists felt that the White Lias proper ought to be grouped with the Rhætic; and yet, at the same time, they realized that it and the underlying Westbury Beds and overlying Watchet Beds were very distinct from the *Pteria-contorta* Black Shales. Hence the suggested dual division of the Rhætic Series into Rhætian and Somersetian: a division supported both upon lithological and upon palæozoological grounds.

In reply to Dr. Marr, the Author thought that if he had altered the term 'Rhætic' to 'Rhætian,' it would have complicated the nomenclature. The term 'Rhætic,' according to the proposed classification, would be available for colloquial purposes in the same way as the terms 'Inferior Oolite' and 'Lias': otherwise, such well-known terms as 'Lias' would have to be modified. 'Rhætian' and 'Somersetian' came into line with such terms as 'Hettangian,' 'Aalenian,' 'Bajocian,' etc.

In reply to Dr. Strahan, the Author exhibited a specimen of *Pteria contorta* from a horizon well down in the Sully Beds at Lilstock in West Somerset, and specimens of this and other fossils from the equivalent beds at Cadoxton and Sully in Glamorgan. Prof. Boyd Dawkins had also recorded characteristic Rhætic fossils from the Sully Beds, or, as they were called at the time, the 'Grey Marls' (*pars*), of Watchet. He agreed with Dr. Strahan and the President that, for mapping purposes, the Sully Beds must be associated with the Tea-green Marls (Keuper). The occurrence in them of Rhætic fossils was of purely scientific interest.

2. *The* RELATIONSHIP *of the* PERMIAN *to the* TRIAS *in* NOTTINGHAMSHIRE.[1] By ROBERT LIONEL SHERLOCK, B.Sc., A.R.C.Sc., F.G.S. (Communicated by permission of the Director of the Geological Survey. Read December 21st, 1910.)

[PLATE V—GEOLOGICAL MAP.]

CONTENTS.

I. INTRODUCTION.

THE Permian System is generally considered[2] to be represented in England by two distinct divisions, corresponding to the Zechstein and the Rothliegende of Germany. The English Rothliegende is further regarded as of two types: that of the Midland Counties, or Salopian type, and that of Collyhurst (Lancashire). The Zechstein is supposed to be represented by the Magnesian Limestone Series of the North-Eastern counties, together with some scanty deposits near Manchester above the Collyhurst Sandstone, and in Cumberland. The red beds of Devon, which are of doubtful age, need not be considered here.

In recent years the Permian age of many of the deposits of Salopian type has been called in question, and it has been shown[3] that, in many cases, they are united to the Carboniferous System below and are unconformable to the Trias above.

In the case of the English Zechstein the beds are magnesian limestones, marls, and sands, and the limestones contain fossils which have been recognized as Permian. This division is chiefly represented by the long belt of strata which stretches continuously from the Northumberland and Durham coast, through Yorkshire, as far south as Nottingham. The Permian in this region differs from the English Rothliegende, not only in lithological character, but in its relationship to the beds below; for it has been known for a long time that it is markedly unconformable to the Carboniferous upon which it rests.

The nature of the upper boundary of the Permian is, however,

---

[1] Thesis approved for the Degree of Doctor of Science in the University of London.

[2] See E. Hull, 1869. [For full details of references, see the Bibliography, § VI, p. 114.]

[3] T. C. Cantrill, 1895; and W. Gibson, 1901.

less clear. It is usually stated that there is an unconformable overlap of the Permian by the Trias in this area; but several geologists, and notably the late Edward Wilson, thought that the gap between Permian and Trias was much overestimated, and that there might even be an actual passage between them.

In this paper I attempt to prove the upward passage of the Middle Permian Marls into Bunter in Nottinghamshire, then, using the Middle Marl as a datum-line, to trace it northwards and to note its relations to the beds above and below and any lithological changes of the strata. The result of this investigation is to show that the 'Bunter' of Nottinghamshire is contemporaneous with the upper part of the Permian of Yorkshire and Durham.

During the years 1903–7 I have mapped, on the 6-inch scale, the Permian outcrop (together with much of the Trias) from its southern limit at Nottingham as far north as Market Warsop. The area of the Permian outcrop is far too great to permit of the examination of the whole in equal detail, but the entire length of it has been traversed, and the chief sections, recorded by Aveline and other geologists, have been examined. In addition, the Permian has been seen at St. Bee's Head and at Penrith.

The chief importance of the work in Nottinghamshire lies in its application to the correlation of the New Red deposits in other districts. A brief account is, therefore, given of the rest of the Permo-Triassic outcrop as far as Northumberland, as well as the supposed equivalent deposits of Cumberland and Manchester, and new correlations with the Nottingham succession are attempted. The palæontology of the Upper Magnesian Limestone is examined, and is shown to lend some support to the new views.

The first considerable paper on the Permian of the north-eastern district is that of Sedgwick,[1] on the geological relations of the Magnesian Limestone, which describes the beds from Northumberland to Nottingham. Later, attention was directed chiefly to the northern part of the outcrop; but in 1861 J. W. Kirkby published an important paper in this Journal, 'On the Permian Rocks of South Yorkshire; & on their Palæontological Relations.'

Geological Survey maps have been issued of the whole area, and memoirs describing the southern half of the outcrop have been published. Recently, two maps and memoirs embodying the results of a re-survey of the neighbourhood of Nottingham have been published.

A paper by Edward Wilson, entitled 'The Permian Formation in the North-East of England,' and dealing chiefly with the mode of origin of the deposits, appeared in the 'Midland Naturalist' vol. iv (1881) pp. 97, 121, etc.

In the year 1877 there were several letters in the 'Geological Magazine' on the relations of the Permian to the Trias near Nottingham. Aveline,[2] who opened the discussion, referred to the

---

[1] Trans. Geol. Soc. ser. 2, vol. iii, pt. i (1829) pp. 37–124.

[2] Geol. Mag. dec. 2, vol. iv (1877) pp. 155–56.

views held by some geologists, that the Permian was perfectly conformable to the Trias in the Nottingham district. To this he objected, on the ground that the Bunter overlaps the divisions of the Permian successively from north to south. Wilson,[1] in reply, pointed out that the successive disappearance of the Permian divisions might be due to conformable overlap, and as an illustration, he cited the case of the thinning of the Marl Slate Series[2] from 60 or 70 feet of shales to 20 feet of sandstones and then to *nil*, between the basal breccia and the succeeding limestone. As a result, the Magnesian Limestone appears to overlap the Marl Slates; he remarks, however, that this points, not to a break, but to the presence of a Permian shore-line to the south.

The Rev. A. Irving[3] supported Wilson, and thought that, while there might be a slight unconformity locally between Permian and Bunter, such breaks were not greater than those that occurred between individual beds of the Permian, and especially between the Middle Marls and the Lower Limestone. In Aveline's[4] reply he states that he did not consider the Permo-Bunter break an important one, and would not give an opinion as to whether the break is more important than that between the Lower Limestone and the Middle Marls. He considers the relationship of the Permian to the Trias an important problem yet to be worked out:—

> 'If a perfect passage from the one up into the other was found, it would go far to settle the question. As far as I know, that passage has not been found, and, I contend, it does not exist in the neighbourhood of Nottingham.'

As will be seen farther on, this passage has now been found.

After Aveline's second letter the discussion ended for the time, but was revived in 1879–82 round the question of the age of the Pennine uplift and the correlation of the Lancashire and Yorkshire deposits. Dr. Irving,[5] who in the interval had been examining deposits in other districts, modified his view of the relationship of the Bunter to the Permian at Nottingham and considered that there must be a break between the two. The discussion need not be further referred to here, as it does not bear closely upon the nature of the Permo-Bunter boundary, but rather on the age of the Pennine uplift.

Other works will be mentioned as occasion arises, and a complete list of references will be found at the end of this paper.

Although the views here expressed on the relations of the Permian and the Trias are opposed to those of Aveline, who mapped much of the area for the Geological Survey, his facts are in no case disputed, but it is hoped to show that new evidence leads to a different interpretation of his results.

---

[1] Geol. Mag. dec. 2, vol. iv (1877) pp. 238–40.

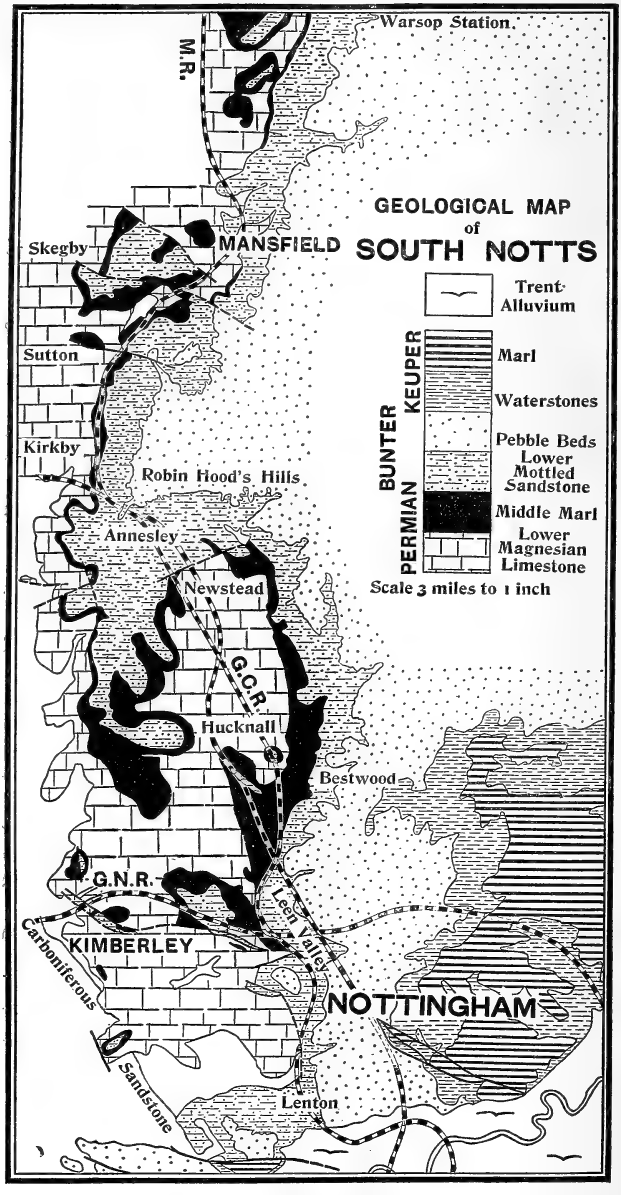
[2] See p. 79 for table of strata.

[3] Geol. Mag. dec. 2, vol. iv (1877) pp. 309–12.

[4] *Ibid.* p. 380.

[5] *Ibid.* vol. ix (1882) p. 163.

Fig. 1.



[The area, west of a north-and-south line through Bulwell, and south of an east-and-west line through Hucknall Common, was mapped on the 6-inch scale by Dr. Walcot Gibson.]

II. STRATIGRAPHY.

(1) South Nottinghamshire.

In this area the succession is as follows:—

Rhætic (fg)	RHÆTIC.
Keuper Marl (f^6)	KEUPER.
Waterstones (f^5)	
Pebble Beds (f^2)	BUNTER.
Lower Mottled Sandstone (f^1)	
Permian (Middle) Marl (e^3)	PERMIAN.
Magnesian Limestone (e^2)	
'Marl Slate' (e^1)	
Breccia	

[The symbols in parentheses are those used on the Geological Survey maps.]

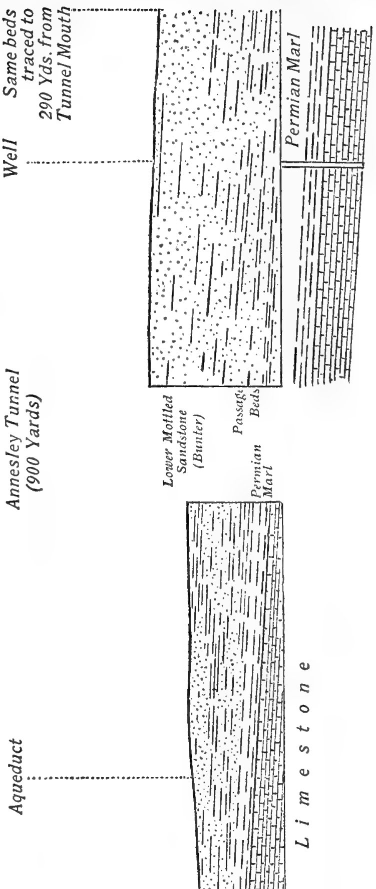
The upper divisions of the Trias may be dismissed in a few words. The Rhætic, the lowest beds of which are best seen at Beaconhill (Newark), is sharply marked off from the Tea-green Marls, which, as usual, form the highest beds of the Keuper. On the other hand, the black shales seem to pass upwards, by the incoming of limestone bands, into the Lias (well seen along the Great Central Railway, south of East Leake Station).

The Keuper Marl presents its usual character of a red silty clay with thin sandstone bands, which increase in thickness and number until sandstone predominates, and the Waterstones come in.

Between the Waterstones and the Bunter Pebble Beds there is probably a slight unconformity. This is indicated by some discordance in strike, by a marked lithological change, and by the presence, at certain places, of a few inches of conglomerate at the base of the Waterstones. The absence of the Upper Mottled Sandstone (f^3) above the Pebble Beds cannot be regarded as evidence of an unconformity, owing to the local character of the Bunter subdivisions. The thickness of the Keuper Marl may be taken as from 600 to 700 feet, and that of the Waterstones as from 80 to 200 feet.

The two divisions of the Bunter differ markedly one from the other, although there is a passage of the lower into the upper (except at Mansfield). The Lower Mottled Sandstone is a fine-grained, rather marly sandrock, of a deep red colour, with sometimes large yellow patches. Rounded pebbles of the usual Bunter type are quite absent, except in the passage-bed at the top, but it contains thin gritty bands, which, at times, are sufficiently coarse to be termed 'breccias.' False bedding occurs, but is much less common than in the Pebble Beds above. The Pebble Beds are considerably false-bedded, with rounded pebbles, either scattered sporadically, or grouped into strings or thin conglomeratic bands, and the sand is

Fig. 2.—*Section on the Great Central Railway between Annesley and Kirkby-in-Ashfield.*



[Horizontal scale: 18 inches = 1 mile. Vertical scale = about 38 times the horizontal.]

coarse-grained. Near Nottingham the beds are yellow or buff; but farther north they become red, though of a paler tint than the Lower Mottled. It is noticeable that the intensity of the redness diminishes with the increased size of the sand-grains. Pebbles and concavo-convex lenticles of red or green marl may occur at any horizon in the Bunter, and are fairly common in the Lower Mottled Sandstone. This sandstone varies in thickness from about 30 feet at Nottingham to 100 feet near Annesley; and the thickness of the Pebble Beds may be taken as varying from 200 feet at Nottingham to 400 feet at Mansfield.

The Middle Permian Marl is a bright red silty clay, with green or greenish-white bands and streaks, which usually are finely arenaceous. Its thickness varies from about 10 to 20 feet.

The Magnesian Limestone is composed of small rhombs of dolomite, cemented by calcareous matter which is dissolved on weathering, when a porous sandy-looking rock of a yellowish colour results. So striking is the resemblance of the rock to sandstone that it has sometimes been described as such in records of borings, and

confused with the Bunter above. At Nottingham the limestone is perhaps 20 feet thick; it increases, however, in thickness northwards, at first slowly, but at Sutton-in-Ashfield rapidly, and then becomes more varied in its characters. It contains a considerable amount of insoluble sandy residue, especially near its southern margin. Fossils are very rare, and consist of casts of lamellibranchs.

The 'Marl Slate' is of local occurrence only. Near Nottingham it is a dolomitic flagstone, which passes upwards into the Magnesian Limestone. Fragments of plants are found in it, together with an occasional *Schizodus* or *Myalina*.

The Breccia, which is even more local than the Marl Slate, is well developed at the southern termination of the Permian outcrop, marking the boundary of the Permian sea.

A little farther north, at the latitude of Kirkby-in-Ashfield, the Marl Slate seems to be represented by grey clays, with occasional thin bands of nearly pure limestone. These latter are interesting on account of the fossils, chiefly lamellibranchs and foraminifera, which they contain. The grey clay, when weathered, closely resembles the soils over the Coal-Measure shales, and, in the absence of the breccia, the Permo-Carboniferous boundary becomes very difficult to trace.

The best sections of the Permian in South Nottinghamshire are along the Great Northern Railway (Derby & Nottingham Branch), and in the cuttings on the Great Central and Midland Railways, near Annesley. The former of these railway-sections was fully described by E. Wilson in 1876, but the Great Central sections have not been hitherto described, except very briefly by myself.[1]

(*a*) Sections on the Great Central and Midland Railways, near Annesley.

Two railways tunnel through the Robin Hood's Hills, 9½ miles north of Nottingham Market Place. One of these, the Great Central main line, approaches the Mansfield Branch of the Midland Railway obliquely, and finally passes under the latter line. The cuttings at the extremities of the two tunnels together show a complete succession, from almost the base of the Magnesian Limestone to the top of the Lower Mottled Sandstone.

Following first the Great Central Railway northwards (see fig. 2, p. 80), the line begins to cut gradually into the plain of nearly horizontal Lower Mottled Sandstone. As successively lower beds are reached the character of the strata is seen to change gradually, the red sandrock becoming very fine-grained with a considerable increase in the proportion of clay, and at the same time developing clay-partings, which give it a flaggy structure. At the entrance to the tunnel, the beds at the bottom of the cutting, now about 50 feet deep, are so fine-grained and marly that it becomes difficult to decide whether they should be regarded as a sandy marl or as a marly

---

[1] W. Gibson & others, 1908, p. 129.

sandrock. These strata bear a close resemblance to the Keuper Waterstones of Nottinghamshire. A well, sunk by the railway company near the mouth of the tunnel, proved the presence of the Magnesian Limestone at a depth of 15 feet below the rails.

The tunnel itself is bricked up, but the section is continued at its northern end. Here the marly beds, seen at the bottom of the cutting at the southern end of the tunnel, have been brought by the gentle dip of the strata to the top of the section. Much of this cutting is unfortunately obscured by grass; but the constant oozing of water from the beds causes landslips, and thus it is possible to make out clearly the whole of the succession.

The marly sandrock of the Lower Mottled Sandstone passes downwards into the red 'Permian Marl' by an increase in the thickness of the marly partings and a corresponding diminution of the fine-grained flags, which eventually come to be represented only by the 'skerries' of the Permian Marl. No true boundary can be traced between the Permian Marl and the Lower Mottled Sandstone; but, for the purpose of mapping them, an arbitrary line was taken below the last considerable sandy lenticular band.

Thus defined, the Permian Marl has a thickness of about 13 feet only. It rests upon the Magnesian Limestone without visible unconformity, but with a sharp lithological break. At the mouth of the tunnel the top of the limestone is 4 feet above the rails, and the low dip of about 1° brings it to the surface of the ground 400 yards from the tunnel. A little farther on the cutting forks, and both branches show good sections of the limestone. The right-hand branch (the Great Northern) turns northwards and becomes parallel to the strike of the beds, so that the section remains in the same part of the limestone; but the left-hand branch, which carries the Great Central main line, turns westwards and cuts through practically the whole thickness of the Magnesian Limestone: the grey marls with fossiliferous limestones, which form the lowest division of the Permian here, cropping out a little beyond the end of the cutting.

The Midland Railway crosses over the Great Central, hence the sections on the Midland are in slightly higher strata than those on the Great Central. Commencing as before in the south, we find that the lowest beds exposed along the Midland line consist of the red sandrock seen close by at the top of the other cutting. Proceeding northwards, the rise of the land-surface causes a deepening of the cutting and brings in increasingly higher strata, until, at the tunnel entrance, we see at the top rather massive and coarse reddish sandrock, which is almost the highest bed of the Lower Mottled Sandstone, for the summit of the hill is in the Pebble Beds.

At the northern end of the Midland tunnel the sections are a repetition of those exposed at the southern end.

These sections are of great importance, because the Permian Marl, which is seen to pass upwards by imperceptible stages into the Bunter, is not, as one might expect, the highest bed of the Permian System, but is the Middle Permian Marl, that is, the marl which

farther north underlies the Upper Magnesian Limestone. There has never been any question raised as to the age of this Marl, which was traced by Aveline from Yorkshire to Nottingham; and detailed mapping confirms the continuity of the bed, at least as far as from Nottingham to Warsop.

If this passage of Permian into Bunter is accepted, there is no escape from the conclusion that the Upper Magnesian Limestone of Yorkshire is of the same age as some part of the Bunter of Nottinghamshire. Although the passage is an apparently perfect one, it might be thought that there is a concealed break somewhere—the break representing the higher Permian beds of Yorkshire. The evidence for a true passage is, however, greatly strengthened by the sections exposed along the Great Northern and Midland Railways, between Nottingham and Kimberley.

(*b*) Sections on the Great Northern and Midland Railways, between Nottingham and Kimberley.

The Great Northern sections were fully described by Edward Wilson in 1876, so that a brief account will suffice here.

The section shows Coal Measures unconformably overlain by a breccia, which is succeeded by the flaggy, calcareous sandstones with shales, known as 'Marl Slates.' These pass upwards into the Magnesian Limestone, here (as usual in South Nottinghamshire) a flaggy rock, composed of rhombs of dolomite set in a cement of carbonate of lime. The limestone is succeeded by red Permian Marls, which appear to pass upwards into a mass of sandstones with bands of marl; and these indefinite strata, which Wilson considered to be a link between the Permian Marl and the Bunter, and for which he therefore used the symbol *ef*, merge imperceptibly into Lower Mottled Sandstone. Wilson, however, did not actually call these indefinite strata 'passage-beds,' as they required further study. A breccia, as much as 5 feet thick, though locally absent, was taken as the base of the true Lower Mottled; but Wilson shows that precisely similar breccias occur well within undoubted Bunter, as, for example, at Kimberley Knowl, close by.

It may be pointed out here that the presence of breccia in the Lower Mottled Sandstone in the Great Northern cutting, and its absence in the Great Central cuttings previously described, is readily accounted for by the proximity of Kimberley to the old shore-line of the Permian sea. The thick basal breccia of the Permian and the sandy 'Marl Slates' above it, similarly contrast with the thin breccia followed by grey marls, found below the Magnesian Limestone near the Great Central cuttings.

Many of the details described by Wilson can still be seen, and the Midland Railway cutting, which is approximately parallel to the Great Northern section, confirms the evidence of the latter.

The presence of the indefinite band of strata between the Permian Marl and the Bunter at Kimberley, 6 miles from the Great Central cutting, strongly confirms the idea that there is a true passage between the two formations.

(*c*) The Area south of the Great Northern Railway (Nottingham & Derby Branch).

A little to the south of the Great Northern Railway, at Basford, the Permian Marl ceases to be separable, and the passage-bed rests upon the limestone for a short distance.

The small faulted outlier at Cinderhill is of interest, as a breccia-band seen there in the quarries has been taken as marking an unconformable junction of the Bunter with the Permian Marl. However, further excavations have shown that the breccia does not always lie at the base of the sandy series, but changes its horizon.

The growth of Nottingham along the Leen Valley and the complicated system of faults which exists there render the stratigraphy very difficult to make out south of Basford; but, from what can be seen at the present time, and from the records of sewer-sections left by Wilson and Shipman,[1] it appears that the passage-bed and Lower Mottled combined thin out southwards. At Bobbers Mill the Magnesian Limestone passes rapidly into a breccia and ends abruptly, and the Lower Mottled Sandstone overlaps it. At Spring Close (Lenton), and also at Two Mile Houses (Basford), there are good sections of variegated Lower Mottled Sandstone, and that rock can be followed to the mouth of the Leen. Here the Bunter, which strikes north and south, is dropped out of sight by faults, proved in the workings of Clifton Colliery: with the result that, on crossing the Trent Valley alluvium, Keuper Marl is seen at the surface.

From the mouth of the Leen, patches of Bunter extend westwards across the Coal Measures, which they overstep; and at the same time the Lower Mottled Sandstone rapidly disappears, so that Pebble Beds come to rest directly upon the Coal Measures about a mile and a half west of the Leen.

(*d*) The Area between the Great Northern Railway (Nottingham & Derby Branch) and the Robin Hood's Hills.

North of the Great Northern Railway the main outcrop of the Permian Marl follows the Leen Valley, and the junction of the Permian with the Bunter is usually hidden by alluvium. The surface of the ground is nearly flat, with a gentle eastward inclination, agreeing in direction with the dip of the beds, the result being that the outcrops of the thin strata are relatively wide. The flat is bounded on the east by the escarpment of the Bunter; and it is interesting to note that the line of feature does not agree with the boundary of the formation—for, owing to their softness, the passage-beds form part of the flat, and it is not until the more massive sand-rock above crops out that an escarpment is produced. This is very well seen in the cutting on the Midland Railway, at the entrance to the tunnel previously described. It is these more resistant beds

---

[1] G. W. Lamplugh & others, Mem. Geol. Surv. 1908, pp. 27–28 & 32–33.

that form the long spur of high ground stretching southwards from the Robin Hood's Hills, through Annesley Park, to near Hucknall Torkard.

At Bulwell Spring, east of the River Leen, a 9-foot section of the passage-bed shows very well the lenticular and inconstant character of the strata.

Wilson[1] states that at Bestwood the passage-beds replace all but 8 or 10 feet of the Lower Mottled Sandstone.

During the construction of the Bulwell Viaduct for the Great Central Railway, sections seen in the excavations were noted by Mr. Allen,[2] engineer to the line, and by J. Shipman. The upper part of the Marl was sandy, though the bottom 8 feet of the section showed nothing but solid marl.

The best exposures, however, of the Permian Marl and Lower Mottled Sandstone, in this area, are in the outliers which occur west of the Leen. Thus the Marl is seen at Bulwell Quarries, where it rests with a sharp junction on the Magnesian Limestone, but appears to pass upwards into Bunter. Farther north, 550 yards south-east of Broomhill, Bunter of very marly character is seen in a sand-pit, and here an actual lateral passage of marl into sandrock can be traced. Another small outlier at Butler's Hill has been cut through by the Great Northern and Midland Railways, showing, obscurely, very marly sandrock resting upon a floor of (Permian) marl.

Details of other sections have been already published,[3] and need not, therefore, be described again.

A curious feature of the Magnesian Limestone, which seems worthy of more notice than it has yet received,[4] is the presence of very sharp anticlinal and monoclinal folds, which form ridges of a distinctly artificial appearance. Aveline noticed some of them, and marked them on the Survey map (Old Series) with the anticlinal symbol. They are, however, fairly numerous, their axes lying in either a north-westerly or a north-easterly direction; and it has been found, by examining the colliery plans, that in several cases the ridge at the surface indicates a fault in the Coal Measures below. The structure of the ridges may be seen in several quarries and on the Great Central Railway near Hucknall Torkard, where the line cuts obliquely through the main ridge. The flaggy limestones, which usually lie almost horizontally, are seen to rise suddenly into an anticline (or sometimes a monocline) having a dip of 20°, 40°, or even more. The base of the anticline is often only some 20 yards wide, and the height of the ridge may be as many feet. The ridges are not continuous for any distance, but are made up of elongated domes arranged along a straight line, or sometimes slightly en échelon. Moreover, mapping has shown that a fault in the Coal Measures below may extend much farther than

---

[1] E. Wilson, 1876, p. 534.

[2] W. Gibson & others, 1908, p. 109.

[3] *Ibid.* pp. 106–10 & 129–30; also G. W. Lamplugh & others, 1908, pp. 27–8 & 31–34.

[4] W. Gibson & others, 1908, p. 108.

the corresponding surface-ridge, which terminates abruptly. It is remarkable that these ridges of dolomite are untouched by denudation, and it seems probable that they were formed by comparatively recent movements along the fault-planes below. These anticlinal domes will be mentioned again when I deal with the districts to the north. They are, however, best seen in the area now described, the most important one extending from Aldercar Wood near Newstead to Bulwell, and forming the boundary of the Permian Marl in the southern half of its course.

(*e*) The Area between the Robin Hood's Hills and Mansfield.

North of the Robin Hood's Hills, the Midland Railway runs along the low-lying Permian Marl to the outskirts of Mansfield, and on the rising ground to the east there are several sandpits in the lower part of the Bunter, which is increasingly argillaceous towards the bottom. At Kirkby Hardwicke the Permian Marl has been almost reached, and at East Kirkby a brickyard shows 16 feet of Permian Marl with a sandy band, resting upon a floor of Magnesian Limestone, and covered by about 6 feet of sandrock (Bunter).

At Sutton Junction a small north-north-westerly fault has cut off an outlier of Permian Marl in Sutton-in-Ashfield. The fault is visible in the Great Northern Railway on the west; while on the east a sandpit, in the Pebble Beds and Lower Mottled Sandstone, shows it.

About a mile and a half beyond Sutton Junction the Permian Marl is cut out by a trough-fault, both arms of which can be seen in a clay-pit, 400 yards north-east of King's Mill. The Marl, however, reappears a quarter of a mile to the east, and can be followed thence into Mansfield.

Between Mansfield and Skegby there is a large outlier of Permian Marl and Lower Mottled Sandstone capped by Drift. Along the southern margin of the outlier a succession of clay-pits display valuable sections, showing the entire thickness of the Permian Marl and its junction with the Bunter above and the Limestone below. The Limestone forms the floors of the clay-pits, and its junction with the Marl seems always to be a well-defined lithological boundary. On the other hand, the Marl is succeeded above by marly sandrock similar to bands occurring within the Marl itself. At first sight, there seems to be a fairly definite boundary below the sandrock; but, on examination, it is seen that this is mainly due to the water which percolates through the sandrock being thrown out by the first bed of Marl which it meets—with the result that the Marl is a little undercut, and the base of the sandrock is bleached to a pale greenish tint.

Here, again, the boundary between Permian and Bunter is purely artificial, and has been taken, as before, at the base of the lowest sandy band of any importance. The Marl, as thus defined, is fairly constant in thickness (about 15 to 20 feet), but

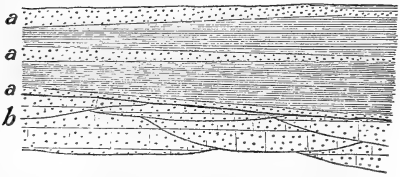
the minor details, such as the position of the sandy bands, vary within the limits of a single clay-pit.

From Nottingham to Mansfield the Permian Marl has been followed continuously as a thin bed of silty clay separating the Bunter from the Magnesian Limestone. At Mansfield, however, the Marl has disappeared, and the Bunter rests directly upon the Limestone. This fact, at first sight, seems to offer support to the theory of an unconformity between the Permian and the Bunter; but a careful examination of the district offers a different interpretation, namely, that the Permian Marl has locally changed its character, and become sandrock indistinguishable from the Bunter above.

The phenomenon of the somewhat sudden disappearance of the Marl at Mansfield does not stand alone. In the same district the Magnesian Limestone, which has also remained fairly constant in character and thickness from near Nottingham to Sutton-in-Ashfield, thickens greatly (at Bestwood[1] the Magnesian Limestone is but 30 feet thick, while at Sherwood Colliery, Mansfield, it is 236 feet), and is divisible into different types of rock. The upper part becomes so sandy, that at Mansfield it forms the well-known building-stones known as the White and Red Sandstones. These 'sandstones' are really composed of about equal parts of sand and dolomitic cement,[2] the red differing from the white merely in the presence of ferric oxide.

At Messrs. Lindley's White Sandstone Quarry (south of the eastern angle of the triangular area marked off by railways on the map) the Marl above the 'sandstone' is worked for bricks. Near the western end of the section the Marl is about 18 feet thick, with green sandy bands; but, as the eastern end of the workings is approached, the total thickness of the Marl decreases considerably, while a sandstone makes its appearance in it and grows rapidly in importance. Portions of the remaining Marl also become sandy, until at the eastern extremity of the section it has become:—

Fig. 3.—*Section at Messrs. Lindley's White Sandstone Quarry, Mansfield.*



[The sandy development of the Lower Magnesian Limestone (*b*) is overlain sharply by Permian Middle Marls, in which sandstone bands (*a*) develop towards the east (left).]

	Thickness in feet.
Sandy pebbly soil, and sand, perhaps slightly slipped ...	3
Red marl, the lower part sandy	3
Fine-grained sandrock, leaden-grey when broken, weathering yellowish	2
Red marl	4
Marly sandrock (intermediate in character)	1
Undulating floor of dolomitic sandstone (e^2).	

---

[1] G. W. Lamplugh & others, 1908, p. 28.
[2] W. T. Aveline, 1879, pp. 10 & 12.

In the Geological Survey Memoir Aveline figures (*op. cit.* p. 17), from information received, an unconformable junction of the dolomitic sandstone with the red marl.

If the sandy bands in the Marl continued to increase westwards, it is clear that a sandrock would result, which might be easily regarded as Bunter; and this would rest directly upon the dolomitic sandstone with apparent unconformity.

An old pit for potter's clay, situated close to the railway-bridge over the Nottingham Road, shows that the Permian Marl still persists, although the outcrop has become very narrow. At Littleworth, a section close to the Brewery shows 8 feet of sandrock with a 3-inch band of marl very near the Limestone: hence there is not room for more than a few feet of marl, if any, between the two. Farther north, sandrock can be seen resting unconformably upon the dolomitic sandstone below the level of the track of the Midland Railway, east of Crow Hill (Mansfield); and there is a good section, showing similar conditions, at Hallam's Grave, north of Mansfield.

Origin of the Mansfield Dolomitic Sandstone.

It seems probable that the local great increase of sandiness in the Magnesian Limestone, and in the Permian Marl above it, have a common cause. Sedgwick[1] inferred that the sandy development of the limestone is confined to the Mansfield district; but this statement must be modified slightly, as very sandy limestones occur in places north of Warsop. However, the fact remains that the Mansfield Sandstone is almost, if not quite, unique.

On attempting to map the dolomitic sandstone, it is found that, as it is followed north-eastwards along the strike, it ceases to remain at the top of the Limestone, but becomes overlain by dolomite, into which it passes upwards gradually, as, for example, at the Rock Valley quarries; and the same conditions are noted if it is followed north-westwards, across the strike. At the Chesterfield Road quarry, one mile north-west of Mansfield, and in the very deep old quarry in Debdale Lane, the 'sandstone' is seen at the bottom of the quarries passing upwards into dolomite. Also at the Chesterfield Road quarry the limestone has been proved underneath the 'sandstone,' which is about 50 feet thick. The sandstone does not crop out again until Pleasley Vale is reached, when it appears at the very base of the Magnesian Limestone, with the grey Lower Marls alone beneath it. It is clear, then, that the sandstone cannot lie at one horizon, but that it is a lenticular mass tilted in a direction opposite to the dip of the beds. If the lenticular mass extends in an easterly, as it does in a westerly, direction, the tilt will carry the sandy conditions into the Permian Marl; and this at once explains the apparent absence of the Marl at Mansfield, as it is there represented by sandy beds which merge into the Bunter sand above.

---

[1] A. Sedgwick, 1829, pp. 83-84.

Such a mass of sand, surrounded by limestone deposits, can be explained by supposing it to have been formed as a sandbank at the mouth of a river, while limestone (or, at a later date, fine silt) was being deposited on every side. The deposition of the sand ever farther eastwards as time elapsed indicates a slow rising of the land, and this might well happen towards the close of the elevation of the Pennine axis; an elevation generally regarded as mainly post-Carboniferous and pre-Permian,[1] but probably not completed until later.[2]

The diagram (fig. 4, p. 90) is intended to illustrate the hypothesis, and also to explain the presence of an outlier of Marl in the western part of Mansfield, opposite the gap in the main outcrop. It is supposed that a river flowed south-eastwards from the Pennines and built up a sand-bar in the shallow Permian sea some miles from the shore. Limestone was deposited all round the bar on every side. The slow rise of the sea-floor caused the sandbank to migrate eastwards to a point where the necessary conditions of depth and currents existed. As a result, it was deposited on the earlier-formed limestone, and, at the same time, limestone forming behind it spread over the earlier sand deposit.

The presence of ripple-marks in the dolomitic sandstone at the Chesterfield Road quarry, and the footprints of reptiles found in the Rock Valley quarry, support the view that the rock was deposited as a sandbank near the land. Shipman (*teste* Mr. Hickling[3]) was also of opinion that the sandstone was formed as a sandbank. Further support is given to this theory of the replacement by sand of the Permian Marl, by the records of Crown Farm Colliery, situated on Bunter Pebble Beds, a mile and a half east of Rock Valley. Here, under 112 feet of Lower Mottled Sandstone, 16 feet of marly beds were met with resting upon limestone, proving that the normal amount of Permian Marl is here present.

The reptilian footprints, and the slight unconformity of the rocks above, show that the sandbank reached the surface at the close of the Magnesian Limestone period. After an interval, a slight subsidence allowed the sandbank to be formed again; but now marl, instead of limestone, was deposited round it.

To make this clearer, fig. 5 (p. 90) is appended. Here a, b, c represent the successive positions of the sea-level, and a', b', c' the sand-bars formed at the corresponding times. The contemporary deposits of limestone are represented by the letters a_1, b_1, c_1. The convergence of the lines a, b, c represents the eastward tilting of the sea-floor.

The deposition of limestone on all sides of the sand-bar offers a difficulty, but the difficulty is not due to the sand-bar theory, for the fact remains that sandstone and limestone can be, and were, deposited in contact and passing one into the other. The mode of origin of the limestone is not understood, except that it is a

---

[1] J. J. H. Teall, 1880, p. 92; E. Wilson, 1880, p. 93.

[2] P. F. Kendall, 1902, pp. 510–13.

[3] G. Hickling, 1906, p. 125.

Fig. 4.—*Diagrammatic section across the Permian at Mansfield: length of section = about 3½ miles.*

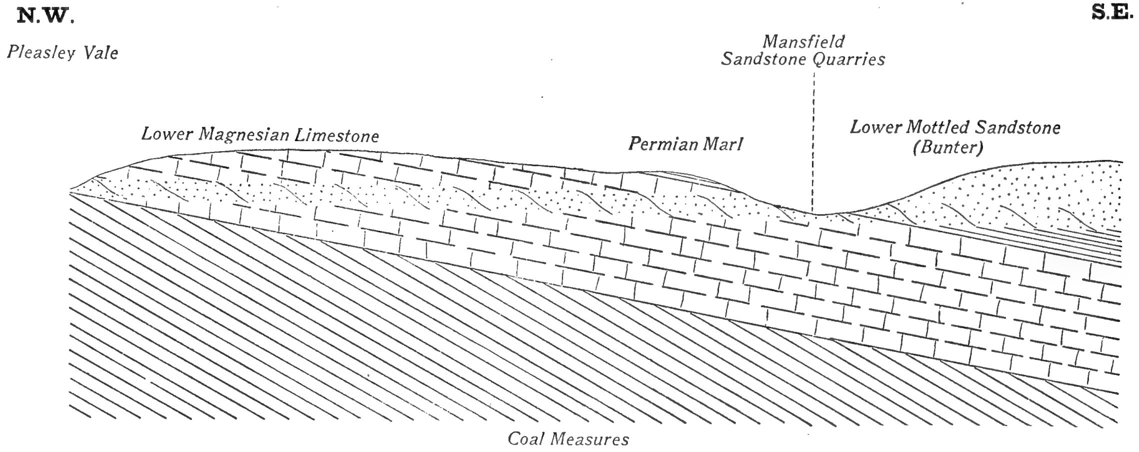
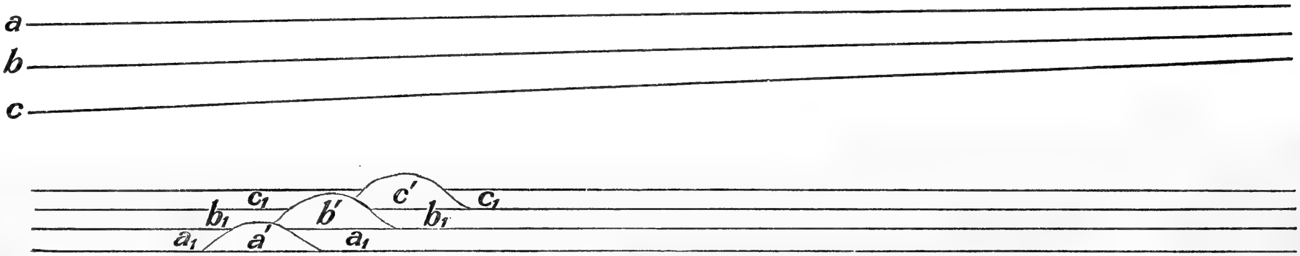


Fig. 5.—*Diagram to illustrate the mode of formation of the Mansfield 'Sandstone.'* (*See p. 89.*)



shallow-water formation, as is shown by its frequent cross-bedding, the presence of sand-grains, and the breccia into which it passes at Nottingham. Sorby (1879, p. 85) considered it to have been formed partly by precipitation and partly from organic débris; but it may be, in part at least, of detrital origin and formed from the denudation of the Carboniferous Limestone of the Pennines.

Rock-specimens were collected from points along the line of section of fig. 4 for microscopic examination, namely: (1) from Baxter Hill, overlooking Pleasley Vale; (2) from the 'Red Sandstone' of Mansfield; (3) from the sandrock in the Permian Marl above the 'White Sandstone,' at Messrs. Lindley's quarry; and (4) from a gritty band in the Lower Mottled Sandstone, at the quarry of the Mansfield Sand Co., Ltd., south-east of the town. The first three differed from the fourth in being dolomitic, but the insoluble residues were all of the same character. The bulk of each residue consisted of quartz-sand, the grains differing somewhat in size in the different specimens, the larger being the more rounded. In addition, the residues contained more or less chert, felspar, and quartzite. These latter constituents are interesting, as their presence was to be expected in sediment derived from the Carboniferous limestones and grits of the Pennines. A specimen taken from near the top of the Pebble Beds, in the railway-cutting between Daybrook and Nottingham, may be mentioned here for comparison. The insoluble residue consisted of coarse quartz-sand with felspar, and a few small grains which are probably chert.

The large outlier between Mansfield and Skegby has been mentioned above (p. 86), but nothing was said of the evidence which it affords of a lateral passage of Permian Marl into sandrock. From Skegby, as far eastwards as Eight Men's Intake, the Permian Marl maintains its normal character and thickness; but, as we trace it still farther eastwards, it is seen to become much more silty, and, at the large clay-pit of the Mansfield Stone & Brick Works, 300 yards south-east of Eight Men's Intake, it is intermediate in character between Permian Marl and Bunter—in fact, it resembles closely the passage-bed seen in the Great Central Railway, already described. The section being an important one, details are given here:—

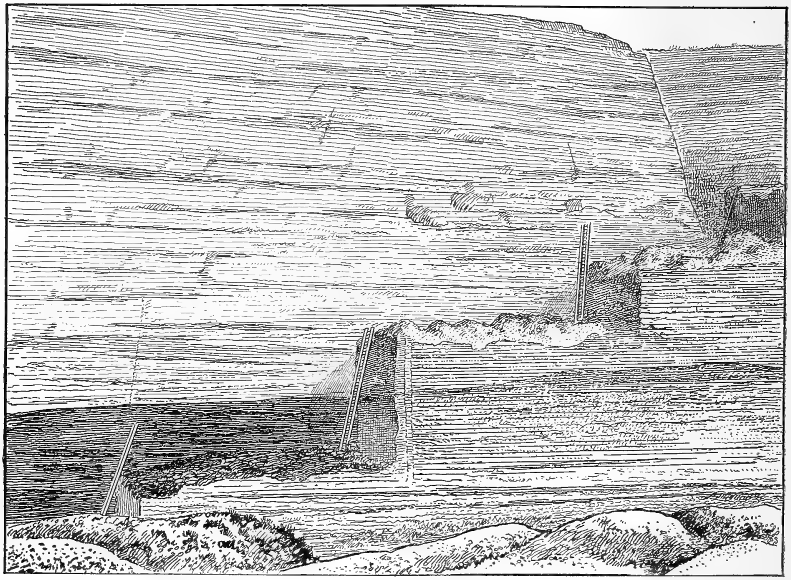
	Thickness in feet	*inches.*
Soil	2	0
Red marl with green streaks	1	6
Red marly sandstone seamed with marl; green streaks...	1	6
Red marl with green streaks	1	6
Hard red marly sandstone	1	3
Do. do. with green streaks	1	0
Red marl	0	4
Red fine-grained sandstone	1	1
Red marl	1	0

The floor is a hard sandstone about 3 feet thick, which has been broken into 150 yards away to the south-east, and is seen to rest upon a somewhat uneven surface of the dolomitic sandstone (Magnesian Limestone). The junction is less marked than usual, owing to both formations being sandy.

To sum up, the sections in the Mansfield district show a lateral passage of 'Permian Marl' into Bunter, as distinctly as the Great Central Railway cuttings, previously described, showed an upward passage.

An unusual feature of the Bunter in the Mansfield district, which may be mentioned here, is the presence of a marked unconformity between the Pebble Beds and the Lower Mottled Sandstone. This is very clearly seen in the huge sand-pit of the Mansfield Sand Co., Ltd., south-east of the town (see fig. 6, above). Here a vertical section, of about 75 feet in all, shows some 45 feet of coarse pink sandrock with occasional pebbles, which are more numerous towards the top, resting on about 30 feet of soft red marly sandrock, quite free from pebbles, but with bands of grit in the lower part. The

Fig. 6.—*The sandpit of the Mansfield Sand Company, Ltd., Berryhill, Mansfield.*



[The sharp line marks the unconformable junction of the Pebble Beds with the underlying Lower Mottled Sandstone. The line is more evident on the left, where the rock has been newly excavated.]

unconformity between the two is a striking one, and pebbles of the eroded Lower Mottled can be found in the Pebble Beds above. The unconformity disappears within a mile on either side of the sand-pit. It seems probable that such a local break would be more likely to occur during deposition at the mouth of a river, rather than elsewhere.

(*f*) The Area between Mansfield and Warsop.

Proceeding northwards from Mansfield, although the base of the Lower Mottled Sandstone is seen to contain many lenticles of Marl, there is no appearance of a distinct band of marl between the Limestone and the Bunter until Mansfield Woodhouse is reached. Here, however, the Marl reappears, and has been traced as far north as Warsop Station, at which point the 6-inch mapping terminated. A large outlier of Marl, not previously known, exists at Park Hall and Nettleworth Manor.

Before leaving this district, mention must be made of the characters of the Magnesian Limestone. To the north of Sutton-in-Ashfield (as has been already stated) the Limestone increases greatly in thickness, and becomes very variable in composition. The famous dolomite which was used in the foundations of the Houses of Parliament is said to have been quarried at Mansfield Woodhouse. Here it occurs as domes, which form hills, rising like islands from the surrounding flat of normal, flaggy, coarse-grained dolomite. The building-stone is a creamy dolomite of fine texture, without any trace of bedding. The mass is divided up into short thick lenticles, by planes which have no special orientation. A further remarkable feature is the presence of cylindrical cavities known as 'gulls,' which may have a diameter of over an inch with a length of several feet, and lie in any direction. They bear a curious resemblance to the holes made by a crowbar for blasting, and, in fact, when their direction happens to be suitable, they are utilized for the purpose. The appearance of the rock suggests swelling as the result of chemical changes. Although the actual junction of the two varieties of dolomite is not visible, they may be seen in quarries within about 200 yards of one another; and it is noticeable that the normal flaggy type shows no sign of an oncoming change, nor is its low dip disturbed.

(2) North Nottinghamshire.

I have not been able to continue the detailed mapping beyond Warsop Station, but the Permian outcrop has been followed along its entire length to its termination in Northumberland, special attention being paid to published sections.

At Warsop, superficial deposits mark the junction of the Permian with the Bunter, and the presence or absence of the Permian Marl can only be inferred. However, a section, described and figured by

Fox-Strangways,[1] at Warsop Colliery Junction, on the Lancashire, Derbyshire, & East Coast Railway, to some extent fills this gap. The Magnesian Limestone was seen to be arched into an anticline, and covered by horizontal Permian Marl and thin flaggy limestones which merged laterally into marl. These thin limestone-bands appear to be 'skerries'—that is, the equivalents of the sandstone bands which occur in the Marl in the country to the south. Just as the sandstone bands increase in importance towards the top of the Marl, until they replace it altogether and give rise to the Bunter, so here it may be that the thin limestones mark the incoming of the Upper Magnesian Limestone which overlies the Marl farther north.

Mr. Bernard Smith informs me that he has found bands of almost pure dolomite interbedded with the Keuper Waterstones at several places, and especially at Westhorpe, near Southwell. These dolomite bands occur in exactly the same manner as the sandstone bands, which are themselves dolomitic. This is a good illustration of how a limestone band such as the Upper Limestone may have been formed contemporaneously with the sandstone of an adjacent area.

Although where the junction of the Lower Limestone and Permian Marl is seen, south of Warsop, it is an abrupt one and is sometimes an unconformity, Mr. J. B. Hill[2] has noticed a passage between the two in the Shirebrook district.

At Cuckney, where the Permian Marl can again be recognized, the Survey map represents it as having a wide outcrop; and on it, at Collingthwaite, is mapped an outlier of the Upper Magnesian Limestone, the southernmost appearance of this member of the series. The outlier is now represented by fragments of weathered limestone lying on the ploughed fields at the top of a hill, and Aveline himself does not seem to have seen more than this. His own account is as follows[3]:—

> 'On the larger of the two outliers the limestone has been quarried. This quarry has been filled up, but the fragments of the stone are strewn plentifully over the field. It is a fine and close-grained stone, of a yellow colour, and it appears from the fragments to be stratified in thin flag-like beds. No fossils were seen in these scattered fragments, though they occur plentifully in the equivalent beds in the north. The existence of the smaller outlier is only indicated by the loose stones lying on the field.'

The second outlier here mentioned is situated about half-a-mile to the north-west of the larger one. The road to Holbeck Woodhouse, immediately under the hill capped by the smaller outlier, shows a good section, in sandrock, which presents precisely the appearance of typical Lower Mottled Sandstone. Aveline,[4] who refers it to the 'Permian Red Marl and Sandstone' (that is, the

---

[1] C. Fox-Strangways, 1898, p. 160.

[2] 'Summary of Progress for 1908' Mem. Geol. Surv. 1909, p. 18.

[3] W. T. Aveline, 1879, pp. 18–19.

[4] *Ibid.* p. 18.

'Permian Middle Marl' of adjacent maps) underlying the Upper Magnesian Limestone, says :—

> 'A good section of these sandstones may be seen in a lane between Woodhouse Hill Farm and Holbeck Woodhouse. Here there are between thirty and forty feet of soft red sandstone in thick beds, except about six feet at the centre, which consists of thin alternations of sandstone and marl. Another section may be seen in a road-cutting about ten chains to the south-east of Woodhouse Hill Farm, consisting of unconsolidated red sand containing a few pebbles, and interstratified with thin beds of more consolidated sand. The thickness of the sand is from twelve to fifteen feet.'

The presence of pebbles is of interest, as they are quite absent in the Permian Marl between Nottingham and Warsop, but are not uncommon in breccia-bands in the Lower Mottled Sandstone. Under the microscope the sand is seen to be quite similar to that from the Lower Mottled Sandstone of Mansfield (see p. 91). If the sandstone seen in the road-cuttings is regarded as Bunter, the limestone becomes a local lenticle in it—quite comparable to that noticed by Fox-Strangways at Warsop Vale, in the Permian Marl, or to one of the 'skerries' in the same marl at many places farther south. Moreover, the sudden expansion of the Permian Marl outcrop coinciding with its change in lithological character, so greatly at variance with the uniform character of the bed between Cuckney and its termination at Nottingham, is at once explained if the upper part of the 'Marl' is regarded as Lower Mottled.

Of the beds between the Lower and the Upper Magnesian Limestone in the district between Welbeck and Tickhill (Sheet 82, N.E.), which have again changed their name and are now called the Middle Marls and Sandstones, Aveline[1] says :—

> 'These beds, consisting of red marls and soft sandstones of various colours, sometimes containing small pebbles, divide the Lower from the Upper Magnesian Limestone. They lie somewhat unconformably on the former, and there is no good section in this district showing a passage upwards into the latter. . . . At Ratcliff there are beds of red sandstone, which might easily be mistaken for the New Red mottled sandstone of the neighbouring districts, if it were not that the strata at Ratcliff are overlaid by red marl; whereas the red and mottled sandstone of the Bunter beds is always overlaid by the Pebble Beds.'

The outcrop of these Marls and Sandstones is very variable in width, and at Letwell, where the Upper Limestone outcrop widens greatly, it becomes proportionately narrow. Aveline[2] remarks that here the thickness has diminished to 20 feet, as compared with more than twice that thickness at Shireoaks.

Here it is to be noticed (1) that the Middle Marls and Sandstones are unconformable to the beds below, as we have seen to be the case elsewhere; (2) that the sudden increase in width of the Upper Limestone outcrop coincides with a marked diminution of the Marls and Sandstones, as if they were replaced by it; and (3) that the Ratcliff beds would have been called Bunter, if sandstone, instead of marl, had been found above them.

---

[1] W. T. Aveline, 1880 (No. 2) p. 18.

[2] *Ibid.* p. 19.

Above the Upper Limestone another division of the Permian, the Upper Marl (e^5), is recognized at two places (north of Carlton and at Whin Common). These occurrences are mapped as lenticles, and there does not seem to be any reason why they should be regarded as Permian rather than Trias, especially as such lenticles of marl do occur in the Bunter, even high up in the Pebble Beds (as, for example, at Blidworth, east of Mansfield). The late Mr. Fox-Strangways informed me that he considered these Upper Marls to belong to the Bunter.

In the north of Nottinghamshire the Lower Mottled Sandstone ceases to be traceable as a separate formation. A road-cutting at Spittal Hill, about a mile east of Tickhill, shows red sandstone of a character intermediate between the typical Lower Mottled Sandstone and the Pebble Beds. It is coloured on the Geological Survey map as Lower Mottled; but the outcrop is marked as very narrow, and is not continued beyond the latitude of Doncaster.

(3) Yorkshire.

North of Tickhill superficial deposits hide the upper limit of the Upper Limestone, and often the lower divisions of the Permian also.

During the cutting of the new South Yorkshire Junction Railway, a temporary section was exposed at Wadworth Carr, about 5 miles south-south-east of Doncaster. Mr. H. Culpin, who drew my attention to the section, informs me that he saw here Triassic sandy strata resting unconformably on the Upper Permian Marl.

It may be that here a local unconformity occurs between the Upper Permian Marl and the Bunter, similar to that already described between the Lower Mottled Sandstone and the Pebble Beds at Mansfield. It is, however, a striking coincidence that the section is precisely on the line of the Edlington Wood fault (see Geol. Surv. map, Sheet 87, S.E.). In these soft strata a fault sometimes bears a close resemblance to an unconformity, and a change in the direction of throw in the Permian (which would apparently be necessary on this explanation) is not uncommon. Instances occur at Skegby and Newbound Mill, where faults proved in the Coal Measures are directly in line with faults throwing in the opposite direction in the Permian. The curious phenomenon of the reversal of the direction of throw of a fault seems to be due to a post-Carboniferous but pre-Permian movement being followed by a slight post-Permian movement in the opposite direction. It may be that the second movement is due to a small recovery of the strata during the period of rest following the upheaval of the Pennine Chain—in fact, a movement of the kind classified by Chamberlin & Salisbury under 'Mutual Adjustment of Continental & Oceanic Segments.'[1] Whatever may be the explanation,

---

[1] T. C. Chamberlin & R. D. Salisbury, vol. ii (1906) p. 236.

however, a difference in the direction of throw in a fault in the Carboniferous and Permian rocks is clearly proved in the Annesley district and elsewhere.

The Wadworth section has been entirely destroyed, but a new one has been opened (August 1909) at a lower level, and this shows the presence of an elongated dome of flaggy limestone below the Marl. The limestone, of which about 10 feet was seen, could be easily matched in the Lower Magnesian Limestone of the Mansfield district. The presence of the anticline, in which the strata have a dip of about 10°, and which is quite similar to those described above as occurring near Hucknall Torkard over Coal-Measure faults, is a further indication that the strata here may be disturbed by the Edlington-Wood fault.

Geological Survey Memoirs have not been issued for the district between Tickhill and Pontefract, although there are notices of the Permian rocks in the Memoir on the Yorkshire Coalfield, and a brief note on the Permian of Pontefract, in the Explanation of Quarter-Sheet 87 N.W.,[1] which do not bear on the present question. Near Tadcaster, however, the Survey Memoir (W. T. Aveline & others, 1870, pp. 9, 10) states that the Middle Marl consists

> 'of red or variegated marls, with beds of soft sandstone sometimes, and in some parts of its range gypsum..... The thickness of the Middle Marl varies considerably; it is sometimes absent altogether, and it is probable that it was very irregularly deposited; the greatest thickness in this district is somewhere about 50 feet..... The Upper Limestone differs considerably from the Lower Limestone, being generally harder, thinly bedded, and full of fossils. It contains little or no magnesia..... [The Upper Red Marl (e^5)] is probably a very thin irregular deposit. It is precisely similar in its lithological character to the Middle Marl.'

Minor unconformities are stated to occur between different members of the Permian formation here. The most important is in the railway-cutting near Tadcaster, where the

> 'Middle Marl has there thinned away to a mere seam, so that the Upper Limestone rests almost directly on the Lower, and at the base of the former there is a thin bed of gravel formed of Lower Limestone pebbles.'

In the Harrogate district Fox-Strangways[2] noted that at the bottom of the system occurs a Lower Marl and Sands very like the Bunter Sandstone, but with thin seams of unctuous white clay, followed by quicksand. Above is the Lower Magnesian Limestone, 175 feet thick. The Middle Marl follows, and is composed of red marls and soft red sandstone, sometimes very like that of Triassic age. The Upper Marl is not known in the district, but the Bunter is represented by 'a soft, brick-red, thick-bedded sandstone, containing occasionally thin marly partings.'

North of this district no information bearing on the present question is to be obtained from the Geological Survey Memoirs.

---

[1] A. H. Green & R. Russell, 1879, p. 11.

[2] C. Fox-Strangways, 1908, p. 11.

A good general account of the Yorkshire Permian was given by Wilson,[1] who classified the beds as follows:—

Upper Marls. 50 feet. A maximum.
Upper Limestone = Brotherton Beds. 30–120 feet.
Middle Marls. 50–30 feet or less.
Lower Magnesian Limestone. { Small-grained Dolomite, about 200 feet.
Lower Limestone, about 120 feet.
Quicksands, Marl Slates, and basal breccia, local and variable.

The Small-grained Dolomite would seem to be the representative of the limestone which forms the knolls of Mansfield Woodhouse. The Lower Limestone is stated to be either thickly or thinly bedded, oolitic or crystalline, with thin marly partings and occasionally ripple-marks. Kirkby [2] gives a list of 31 species of fossils obtained from it in South Yorkshire: of these it has eleven species in common with the Compact Limestone of Durham (lowest division); but 29 species occur also in the Middle (Shell) Limestone of Durham. The Small-grained Dolomite is practically unfossiliferous. The Middle Marls are very variable in thickness. Sedgwick [3] states that they are absent north of the Wharfe; and south of that river also they are sometimes absent (as, for example Tadcaster).

The Upper Limestone (or Brotherton Beds) comprises thinly-bedded, white or grey, red or yellow strata, with little or no magnesia. They exhibit marly partings, ripple-marks, and sun-cracks. The fossils are of very few species.

The Trias of Yorkshire is divided into two broad divisions [4]: an upper, consisting almost exclusively of marls with gypsum; and a lower, more variable division, in which sandstone greatly predominates. These divisions correspond broadly with the Keuper and the Bunter.

The Bunter is not capable of subdivision, even in the south of Yorkshire; and north of Ripon it cannot be separated at all from the rest of the Trias. Deep borings have increased rather than diminished the confusion, for Keuper characteristics may occur in rocks which, from their position, ought to be Bunter. Prof. Kendall remarks that the most that it is prudent to assert is, that Keuper characteristics are more frequent at the top of the sandstone series, while those elsewhere diagnostic of Bunter prevail more near the base.

---

[1] E. Wilson, 1881, p. 189.

[2] J. W. Kirkby, 1861, p. 310.

[3] A. Sedgwick, 1829, p. 103.

[4] P. F. Kendall, 'Geology' in the 'Victoria County History of Yorkshire 1908, p. 5 (reprint).

(4) Durham County.

Prof. Lebour[1] has recently classified the Permian and Trias in this county as follows:—

Period.	*Formation.*	*Character of Material.*	*Thickness in feet.*
SALT MEASURES (Trias above, Upper Permian below).	Keuper Red Sandstones and Marls passing downwards into similar Permian Sandstones, etc.	Mostly red rocks with deposits of rock-salt, gypsum, anhydrite, and thin magnesian limestones towards the base.	up to 1200
PERMIAN.	Magnesian Limestone.	Often concretionary.	up to 800
	Marl Slate.	Flaggy calcareous beds: fish-remains.	up to 15 (usually 3)
	Yellow Sands (Quicksands).	Generally yellow, but sometimes dark-coloured, more or less incoherent, water-bearing sandstone.	up to 104

He remarks that the subdivision of the limestone is difficult, and that the following scheme drawn up by the late R. Howse is only tentative, although the best available up to the present:—

(*f*) Upper yellow limestone and (*e*) botryoidal limestone.	UPPER GROUP (3).
(*d*) Cellular limestone and (*c*) shell limestone.	MIDDLE GROUP (2).
(*b*) Compact limestone and (*a*) a conglomerate at the base.	LOWER GROUP (1).

Here the Middle Marls of South Yorkshire have disappeared, and are presumably represented by limestone.

The Upper Group of Durham is lithologically very remarkable, and contains the well-known concretionary limestone of the Durham cliffs,[2] which cannot be matched in Yorkshire.

The thickness of the Magnesian Limestone Series varies from 800 to as little as 299 feet at Whitehouse, Norton, and even this small thickness contains shale, gypsum, and nearly 90 feet of anhydrite.[3]

In Northumberland only the lower divisions of the Zechstein are present.

The Salt Measures above the Limestone are of great interest, and there has been much discussion as to their age. According to the Geological Survey map, the Magnesian Limestone is immediately overlain by Keuper Waterstones; Prof. Hull[4] thinks that the salt-rock proved in the Middlesbrough boring occupies the geological position of that which occurs in Cheshire, Staffordshire,

---

[1] G. A. Lebour, 'Geology' in the 'Victoria County History of Durham' p. 2 (reprint).

[2] E. J. Garwood, 1891.

[3] T. Tate, 1892, p. 493.

[4] E. Hull, in Bell, 1887, p. 155.

etc. (that is, it is of Keuper age). The late C. E. de Rance thought (Rep. Brit. Assoc. 1885, p. 384) that

> 'the pebbly character of the middle portion of the Bunter has died away northwards, and that the Middlesbrough section represents Waterstones, pebbleless Middle Bunter, and Lower Bunter.'

Prof. Lebour's view is indicated by the classification tabulated on the preceding page.

Dr. Woolacott[1] has recently suggested a new classification of the Permian of the North-East of England, which places 300 feet of the Salt Measures in the Permian, and to this portion he gives the name of 'Middlesbrough Red Beds with Salt.'

Sir Andrew Ramsay,[2] referring in 1880 to Messrs. Bell Brothers' trial-boring at Saltholme, stated that 1175 feet of red sandstones and marls, with beds of rock-salt and gypsum, were passed through. These strata he considered to be Keuper Marls and sandstones. Beneath these came 67 feet of dolomitic limestone, which, he said, in this neighbourhood forms the upper part of the Permian Series; and beneath the limestone the strata consist of 27 feet of gypsum, rock-salt, and marls, one of the beds of rock-salt having a thickness of 14 feet. Wilson[3] described the 67 feet of dolomitic limestone as 'indurated marls,' and averred that they did not resemble any known beds of the Magnesian Limestone of Durham, but had the greenish-grey colour of certain Keuper Marls: therefore, he referred the whole of the strata passed through in this boring to the Keuper. Wilson thought it most improbable that the upper part of the boring was in Keuper and the lower part in Permian, because of the unlikelihood of an uncommon mineral, such as rock-salt, occurring at two horizons, within 200 feet of one another in the same vertical section, in two distinct rock-series. He added that the chances against such a coincidence are vastly increased, when we consider that there is no sort of sequence between the two formations in the district in question, but that, on the contrary, there is a decided break and unconformity between them—indicated by the omission of the whole of the Bunter and Muschelkalk. He also remarked that this discordance between Permian and Trias in Durham is probably, in large measure, due to want of conformity between the Keuper and the Bunter, coupled also perhaps with an original northward thinning-out of the Bunter Sandstone.

Mr. H. H. Howell, in 1890, gave his reasons for recommending that all the red rocks, between the Rhætic and the Durham Permian limestones, should be classified as Keuper on the Geological Survey maps. He states that he has examined the rocks which underlie the undoubted Keuper at the few places where they crop out from under the Drift, and that they have a distinctly Keuperian aspect and are not in the least like Bunter. The cores of borings

---

[1] D. Woolacott, Rep. Brit. Assoc. 1909.

[2] A. C. Ramsay, 1880, p. 11.

[3] E. Wilson, 1888, p. 771.

confirmed him in this opinion: he found no trace of a break or unconformity within the red rocks—they seemed due to one continuous deposition—and he felt compelled to carry down the base-line of the Keuper to an horizon where the lithological characters were marked and distinct, namely, to the junction with the Durham Permian Limestone. At this horizon there is some evidence of a possible unconformity. At Seaton Carew the red rocks rest upon the upper division of the Limestone, which crops out at Hartlepool. A boring on the north side of the Tees yielded *Axinus dubius* and a roestone bed similar to one in the cliffs at Hartlepool, indicating that the red rocks rest upon the same horizon of the Limestone as at Seaton Carew. But, at the western outcrop of the red rocks near Darlington, Leeming Lane, and Ripon they rest (with a thick bed of gypsum at the base) upon the fossiliferous and compact limestone of the Durham Permian—that division which immediately overlies the Marl Slate. Mr. Howell objected to Wilson's description of the limestone at Saltholme as 'indurated marl,' and gave an analysis showing that it contains over 95 per cent. of carbonates of calcium and magnesium. He also quoted Howse's view that this limestone and the accompanying marl are identical with the Upper Limestone and Red Marl of Sedgwick, and the Brotherton Beds and Red Marl of Kirkby, as exposed at Brotherton and other localities in South Yorkshire.

Many other borings have been put down in the Durham salt-district, which for the most part pass through strata similar to those at Saltholme[1]; but the only one requiring mention here is that at Seaton Carew, mentioned above, which was made by Messrs. Casebourne & Co. in 1887. Rock-salt was not met with in this case; but the boring was continued into the Carboniferous, and proved that the Magnesian Limestone was 878 feet thick.

It appears from the conflicting evidence just adduced that nothing is certainly known as to the age of the Salt Measures. The unconformities which different geologists would place at different horizons of the strata passed through by the boring seem to be fixed on purely hypothetical grounds, except the one at the top of the Durham Permian Limestone. That there is an unconformity in some parts of England between the Keuper and the Bunter is probable, and in fact detailed mapping indicates that this is the case near Nottingham. The unconformity is, however, often assumed, in order to account for the apparent absence of the Muschelkalk; and it is far from certain that this formation is not represented in parts of England by sediments. Mr. Woodward[2] thinks that this is the case in Devon, and, recently, Mr. Wills[3] has shown that certain beds which have the appearance of Lower Keuper are not improbably of Lettenkohle, or Muschelkalk, age.

---

[1] E. Wilson, 1888, p. 765.
[2] H. B. Woodward, 1874, p. 389.
[3] L. J. Wills, 1910, p. 268.

(5) The Evidence from Deep Borings.

In addition to the deep borings in the Middlesbrough district, mentioned for convenience in the last section, a number of borings have been made in search of coal or water through the New Red rocks farther south.

In most cases, when boring through New Red rocks, it is impossible to say at what depth a particular division was met with, so that the thicknesses given generally are merely approximate. No boundary-line, for example, can be drawn between Pebble Beds and Lower Mottled Sandstone; and often the junction of the Bunter with the Keuper and the Permian would be taken at different horizons by different authorities. Making allowance for this difficulty, however, the borings are of great interest, since they enable us to trace the Permian deposits away from the Permian coast-line into what was presumably deeper water.

At Gedling Colliery[1] (situated about 3 miles north-east of Nottingham Market Place) the Bunter is 385 feet thick, and the Permian consists of 46 feet of grey shales with 8 inches of basal breccia.

At Thurgarton boring, 6 miles to the north-east of Gedling, the Bunter was 494 feet and the Permian was about 93 feet thick. The latter consisted of red and blue shales with sandstone bands, a thin seam of gypsum, and a basal breccia. Possibly these beds represent the Marl Slates, Limestone, and Middle Marl. The absence of limestone at Gedling and Thurgarton is remarkable.

At Bestwood Colliery, 5 miles north-north-west of Nottingham, the shaft was commenced in Bunter, and passed through 19 feet of the Middle Marls and 30 feet of Limestone into Coal Measures.

At the Oxton coal-boring, 5 miles north-east of Nottingham, below 374 feet of Bunter Sandstone, there was 9 feet of 'Permian Marl,' Limestone 45 feet, Marl Slate 85 feet, and Basal Breccia 2½ feet.

At the Crown-Farm Colliery, Mansfield, where the shaft was commenced in Bunter Pebble Beds, the Lower Mottled Sandstone was 112 feet thick, and was followed by 16 feet of Marl with micaceous sandy bands, then Limestone 67 feet, Marl Slate 98 feet, and Breccia 3 feet.

At Southcar[2] (also known as Haxey) the New Red consisted of

			Thickness in feet	*inches.*
	Upper Keuper (incomplete)		105	7
	Lower Keuper		608	7
	Bunter		434	4
Permian.	Upper Marls.	Marls (with gypsum)	7	0
		Anhydrite	8	10
		Marls and sandstones (with gypsum).	73	1
	Upper Magnesian Limestone		53	0
	Middle Marls (with gypsum)		132	9
	Lower Magnesian Limestone.	Magnesian Limestone, with a little marl and gypsum near the top and 15 feet of shale at the base	273	1
	Coal Measures.			

---

[1] W. Gibson, in 'The Geology of the Country between Newark & Nottingham' 1908, pp. 13–17.

[2] G. Dunston, 1896–97, p. 522.

The boring at Barlow, near Selby, is also an important one. The following section is taken from Mr. Durnford's paper, where full details are given (1907–1908, p. 437):—

	Thickness in feet.
Alluvium	94
Sandstone with occasional marl bands	611
Red and mottled marls	39
Gypsum and anhydrite	20
Red marl with gypsum	26
Magnesian Limestone	103
Red marl (with limestone layers)	64
Rock-salt	20
Limestone (with layers of anhydrite and marl) ...	317
Coal Measures.	

Mr. Durnford thinks that the highest bed of anhydrite is that which occurs at Southcar. Whether the beds above are of Keuper or of Bunter age is a matter of controversy.

(6) Cumberland and Westmorland.

Strata belonging to the Upper Permian formation occur in the Eden Valley and at St. Bees Head, and there are also a few small patches south of the Lake District.

According to Goodchild (1891–92, pp. 22–24), the succession in Cumberland and Westmorland is as follows:—

	Maximum thickness in feet.
B_3. Upper New Red.	
5. Keuper Marls. Red marls with rock-salt, gypsum, subordinate flagstones, and, near the base, thin beds of magnesian limestone	?+950
4. St. Bees and Kirklinton Sandstones. Mainly of a Venetian-red colour, with subordinate strata of red sandy shale or marl. The series may be divided into:—	
(iv) An uppermost band of cellular rock (Waterstones).	
(iii) Zone characterized by tile-red colours (Kirklinton Sandstone).	
(ii) Venetian-red sandstones, with occasional white bands and a local development of fine conglomerate (Pebble Beds).	
(i) Variegated zones (Lower Mottled) graduating into the next subdivision.............. Total	2000
3. Gypsiferous Marls (Bunter Marls); chocolate and Venetian-red shales, with subordinate micaceous flags, large segregations of gypsum at various horizons. A band of conglomerate occurs locally at the base, which reposes discordantly upon various members of (2) and (1)	300

[Cumberland & Westmorland succession.]

	Maximum thickness in feet.
B_2. Magnesian Limestone Series.	
2^{ii}. Magnesian Limestone. Impure cellular dolomite ...	0 to 10
2^{i}. Plant Beds (Marl Slate). Alternations of dolomitic sandstones with thin bands of impure dolomite, clays and shales, bands of lignite, and occasional thin coals. Remains of *Nœggerathia*, *Walchia*, *Ullmannia*, and bracts of cones. In the Helton Section these beds may be	150
B_1. Lower New Red or Roth-todt-liegende.	
1^{iv}. Copper-red sandstones, usually devoid of mica and generally containing much secondary quartz. Exhibit footprints.	
1^{iii}. Upper Brockram; breccias of angular fragments of Carboniferous rocks.	
1^{ii}. Penrith Sandstone as 1^{iv}, but much more false-bedded, and usually coarser (unfossiliferous).	
1^{i}. Lower Brockram, as 1^{iv} [? 1^{iii}]. The maximum thickness near Appleby may be 1500 feet, but its extreme variability and excessive false-bedding render any exact estimate almost impossible.........	? 1500

On the north-east side of St. Bees Head there is a well-known section, showing Magnesian Limestone (2^{ii} in the foregoing table) with casts of fossils, resting on 3 feet of breccia, which overlies unconformably Carboniferous sandstones. Above the limestone there is some 30 feet of red marl, succeeded by a 15-foot bed of gypsum, which was mined until recently. A second bed of gypsum succeeds this, separated by 2 or 3 feet of marl; and, still higher, there is an alternation of red marl and fine-grained sandstone-bands with flakes of mica. These strata are very like the passage-beds between the Permian Marl and the Bunter seen in Nottinghamshire, and like them they pass up into sandstone, in this case the St. Bees Sandstone.

Sedgwick,[1] who first described this section, considered the St. Bees Sandstone to be of Bunter age, and, seeing no break in the succession, named everything above the Magnesian Limestone, Trias. Later, in 1864, Murchison & Harkness, recognizing the gypsiferous marls above the limestone as the equivalent of Murchison's Upper Permian (Bunterschiefer), were for the same reason obliged to assign the whole of the St. Bees Sandstone to the Permian: for it was considered, at that time, that there must be an unconformity between the Permian and the Trias.

Mr. T. V. Holmes (1881) agreed with Murchison in referring the whole mass to the Permian; whereas Goodchild followed Sedgwick, and made everything above the limestone Trias. Dr. Irving [2] also holds that the St. Bees Sandstone is of Bunter age.

Mr. Holmes regards the Kirklinton Sandstone as Lower Keuper

---

[1] A. Sedgwick, 1836, p. 398.

[2] A. Irving, 1882, p. 163.

and younger than the St. Bees Sandstone. He also considers that the Permian and the Trias are closely related; but Goodchild went farther, and united them into a New Red Sandstone System.

(7) Manchester District.

The Permian rocks near Manchester are known chiefly through the researches of Binney (1841 & 1846). The following is his classification.[1] In descending order there are:—

	Thickness in feet.
1. Strata of red and variegated marls, containing thin layers of limestone and gypsum, and beds of sandstone; they contain fossil mollusca of the genera *Schizodus*, *Bakevellia*, *Pleurophorus*, *Turbo*, *Rissoa*, etc.	about 300
2. Conglomeratic brown sandstone	about 50
3. Soft red or variegated sandstone (Collyhurst)	about 500
4. Conglomeratic sandstone (Astley), with pebbles of white quartz and shingle with impressions of coal plants	about 60

The fossils occur only in the red or variegated marls and their numerous limestone-intercalations. They comprise 21 species in all, which, H. B. Geinitz (1890, pp. 539 *et seqq.*) says, establish the Upper Zechstein age of the variegated marls.

Binney[2] was unable to point out a line of division between the Permian and the Trias, and Geinitz says:—

> 'In all cases where the variegated clays of the Upper Dyas or Upper Permian, and those of the Lower Trias or Upper New Red Sandstones are found in juxtaposition and actual contact, they appear, by the conformability of their stratification, to be intimately linked together..... Where, again, the upper limestone appears more independent and of the character of a pure marine formation, there is much less temptation to refer the variegated clays or red clay shales at the basis of the variegated sandstone to the Dyas.' (Trans. Manch. Geol. Soc. vol. iv, 1864, p. 133.)

In the discussion on the paper, Binney stated that the Permian and the Trias (near Manchester) apparently passed into one another, and were inclined at the same angles. They could only be distinguished by the fossils in the lower beds.

III. PALÆONTOLOGY OF THE UPPER MAGNESIAN LIMESTONE.

The Bunter formation may be described as unfossiliferous in England. A few imperfect plants have been recorded, as, for example, those found by Mr. R. D. Vernon[3] at Colwick, Nottingham, in the uppermost layers of the Pebble Beds; but these are of no value for chronological purposes. In the absence of determinable fossils, it is clearly impossible to say what animals and plants were in existence during the period of the English Bunter; and it is unsafe to assume that, if fossils should ever be found in these rocks, they will prove to belong to a different period from those known to occur in the Upper Magnesian Limestone of the English Permian.

---

[1] In Geinitz, 1890, p. 538.

[2] In Geinitz, 1864, p. 145.

[3] G. W. Lamplugh & others, 1908, p. 42.

The stratigraphical evidence already adduced points to the Upper Magnesian Limestone being contemporaneous with part of the Bunter. It will be useful now to give some account of the palæontology of the Upper Magnesian Limestone.

The most important work on British Permian Palæontology is King's 'Monograph of the Permian Fossils of England' (1860), which gives a complete account of all that was known of the subject at the date of publication, and is still a standard work. J. W. Kirkby (1861) described the fauna of the South Yorkshire Permian, and gave a list of the species known at that time from the Upper and Lower Limestones; and a few additional species are mentioned in the Survey Memoirs. A full list of the species in the Lancashire Permian is given by Geinitz,[1] with an addition by Mr. Roeder.[2]

Combining the lists from these (apparently the only) sources, we find that the fauna and flora of the Upper Magnesian Limestone comprise:—

PLANTÆ.

ALGÆ.

Spongillopsis dyadica Geinitz.
Chondrus (?) binneyi King.

CONIFERÆ.

Voltzia liebeana Geinitz.

PALMÆ.

Guilielmites permianus Geinitz.

ANIMALIA.

RHIZOPODA.

Dentalina permiana Jones.
Dentalina kingii Jones.
Dentalina (?).
Textularia triticum Jones.
Textularia cuneiformis Jones.

SPONGIÆ.

Tragos binneyi King.

VERMES.

Spirorbis permianus King.
Vermilia obscura King.
Serpula (?) pusilla Geinitz.
Filograna permiana King.

LAMELLIBRANCHIATA.

Avicula (Monotis) kazanensis de Vern.
Avicula (Monotis) garforthensis King.*

LAMELLIBRANCHIATA (cont.).

Mytilus septifer King.
Mytilus squamosus J. de C. Sow.
Myalina hausmanni Goldf.
Bakevellia antiqua Münster.*
Leda vinti King.
Leda speluncaria Geinitz.
Pleurophorus costatus Brown.
Schizodus schlotheimi Geinitz.
Schizodus rotundatus Brown.
Schizodus truncatus King.
Schizodus obscurus (J. Sow.).
(?) Edmondia elongata Howse.
Cleidophorus pallasi (de Vern.).

SCAPHOPODA.

Dentalium speyeri Geinitz.

POLYPLACOPHORA.

Chiton (?).

GASTROPODA.

Turbo helicinus Schlotheim.
Turbo mancuniensis Brown.
Turbo permianus King.
Rissoa obtusa Brown.
Rissoa leighi Brown.
Rissoa gibsoni Brown.
Natica minima Brown.

PISCES.

Gyropristis obliquus Agassiz.*
Palæoniscus longissimus Agassiz.*
Palæoniscus catopterus Agassiz.*

The species marked with an asterisk * are described by King

---

[1] H. B. Geinitz, 1890, pp. 551–52.

[2] C. Roeder, 1892, p. 113.

as 'probably' belonging to the highest Permian deposits. In the foregoing list the genera have been arranged in classes, according to the classification adopted by Zittel in his 'Grundzüge der Paläontologie' (1903).

Many of the generic and specific names have been altered by later palæontologists; and the list given would be considerably reduced, if it included only those forms which are generally acknowledged to be distinct species. Thus Kirkby united all the four forms of *Schizodus* into one species, *Axinus obscurus* Sow.: which would now become *Schizodus obscurus* (Sow.), or *Myophoria obscura*, if, with Prof. Steinmann (1907), we regard *Schizodus* as inseparable from *Myophoria*. Similarly, Kirkby considered the two species of *Mytilus* to be inseparable from *Myalina hausmanni* Goldf. King (with some hesitation) placed these forms in two species of *Mytilus*, but Dr. Wheelton Hind (1897, p. 104) seems to infer that they are really *Myalina*, and adds that

> 'one is seemingly warranted in characterizing *Myalina* as a freshwater genus.'

Zittel, in his 'Grundzüge' (1903), gives Silurian and Devonian as the range of *Myalina*, and Trias to recent for *Mytilus*; while Prof. Steinmann regards *Myalina* as part of the genus *Gervillia*.

Monotis is Triassic only, according to Zittel: Geinitz[1] made it a subgenus of *Avicula*. *Bakevellia* was placed by him as a subdivision of *Gervillia*, but was accepted as a distinct genus by Zittel. Prof. Steinmann does not mention the name at all, having apparently included it under *Gervillia*.

Leda speluncaria Gein. is considered by King to be the same as *L. vinti* King. The *? Edmondia elongata* Howse, recorded at Manchester by Geinitz, would appear to be wrongly named, since the range of *Edmondia* is given by Zittel as Carboniferous.

Cleidophorus is stated by Zittel to range from the Silurian to the Devonian. The range in time of *Dentalium* is given by the same authority as Silurian to recent.

Geinitz thought that *Turbo mancunensis* Brown was included in *T. helicinus* Schl., and that *Rissoa gibsoni* Brown is probably the same as *R. leighi* Brown.

Of the sponge *Tragos binneyi* King, Dr. Hinde[2] says:

> 'The type-specimen, now in the Museum of Queen's College, Galway, shows no traces of organic structures, and appears to me to be of inorganic origin. It comes from Bradford, near Manchester.'

The Vermes are, of course, fossils of very indefinite characters. *Vermilia* is not mentioned by Zittel, and appears to be referred now to *Serpula*. Geinitz thought that *Filograna* might be a pteropod: this name, also, seems to be no longer recognized.

The fish *Gyropristis* is not mentioned in Dr. A. S. Woodward's 'Vertebrate Palæontology'; but, in Woodward & Sherborn's[3]

---

[1] H. B. Geinitz, 1890, p. 551.

[2] G. J. Hinde, pt. ii, 1888, p. 183.

[3] A. S. Woodward & C. D. Sherborn, 1890, p. 91.

'Catalogue of British Fossil Vertebrata,' it is described as a ? Permian ichthyodorulite from Belfast.

Algæ are notoriously unsatisfactory as fossils, and it is not surprising that both the generic names seem to have been dropped. *Voltzia* is retained by Dr. Kidston[1] as a Permian genus, and he states that the specimens from Saxony in the British Museum referred to *V. liebeana* Gein. appear to be the bracts of a *Voltzia* cone. There are probably no palms in the Permian; and *Guilielmites* is a doubtful genus of Tertiary age (Schimper).[2]

Retaining the forms which are only 'probably' from the Upper Limestone, but leaving out the bad and doubtful species, which are useless for correlation purposes, the following are left:—

PLANTÆ.

CONIFERÆ.

Voltzia liebeana Geinitz.

ANIMALIA.

RHIZOPODA.

Dentalina permiana Jones.
Dentalina kingii Jones.
Textularia triticum Jones.
Textularia cuneiformis Jones.

VERMES.

Spirorbis permianus King.
Serpula (?) pusilla Geinitz.

LAMELLIBRANCHIATA.

Avicula (Monotis) kazanensis de Vern.
Avicula (Monotis) garforthensis King.

LAMELLIBRANCHIATA (cont.).

Myalina hausmanni Goldf.
Bakevellia antiqua Münster.
Leda vinti King.
Pleurophorus costatus Brown.
Schizodus obscurus (J. Sow.).
? Edmondia elongata Howse.
Cleidophorus pallasi (de Vern.).

SCAPHOPODA.

Dentalium speyeri Geinitz

GASTROPODA.

Turbo helicinus Schlotheim.
Turbo permianus King.
Rissoa gibsoni Brown.
Natica minima Brown.

PISCES.

Palæoniscus longissimus Agassiz.
Palæoniscus catopterus Agassiz.

Considering the dates at which these fossils were named, it is probable that, if they were examined by modern specialists, the list would undergo considerable modifications.

If we consider now the affinities of this fauna and flora, we find that they are unquestionably Mesozoic.

The Rhizopoda and the *Serpula* belong to living genera, although none of them are of any importance from the point of view of affinities. Of the Lamellibranchs, Zittel states that *Avicula* and *Leda* are still living; *Pleurophorus* ranged from the Devonian to the Trias; *Bakevellia* is confined to the Permian, but the range of the family to which it belongs (the Pernidæ) is said to be from the Permian to the present time. Zittel does not recognize either *Edmondia* or *Cleidophorus* as occurring in the Permian, hence these forms probably are wrongly named generically, and in fact the *Edmondia* was queried by Geinitz. *Schizodus* occurs in the

---

[1] R. Kidston, 1886, p. 17.

[2] W. Ph. Schimper & A. Schenk, 1890, p. 372.

Carboniferous (W. Hind, 1897) and Permian, but is Permian only according to Zittel; and the genus is barely separable from *Myophoria*, which is so typical of the Trias (see Steinmann, Waagen,[1] and Wöhrmann[2]).

From what has been said above, it is evident that the genus of *Myalina hausmanni* is quite uncertain, and its affinities are therefore also uncertain. However, a species occurs in the Middle Bunter[3] of Germany, which is so like *M. hausmanni* that for a long time it was mistaken for it.

The scaphopod *Dentalium* is a persistent type, which still exists.

Turning to the Gastropoda, we find that the genus of the *Natica* is doubtful; but, if the determination be correct, all the gastropoda recorded belong to genera which are still living.

The genus *Palæoniscus* is usually regarded as an important link with the Palæozoic, but the genus is exclusively Permian (A. S. Woodward, 1898, p. 86).

The plant *Voltzia* is typical of the Bunter, and is unknown in the Carboniferous.

Many of the fossils in the list are of restricted range, as, for example, the Rhizopoda, which are recorded only from Dyer's Quarry (Durham). The two species, *Myalina hausmanni* and *Schizodus obscurus*, are by much the commonest fossils, and in South Yorkshire and Nottinghamshire the only fossils that are found. Their wide distribution enables us to correlate the Upper Magnesian Limestone of England with the upper part of the German Zechstein, although it is to be remembered that both species occur also in the Lower Magnesian Limestone.

The southernmost occurrence of the Zechstein in Germany is near Heidelberg; but in the Bavarian Palatinate, on the other side of the Rhine, there occurs a dolomitic bank, in red chalky beds and clayey sandstones, which were regarded as Bunter, until *Myalina hausmanni* and *Schizodus obscurus* were found in them. Here we have proof of a Bunter facies of the Upper Magnesian Limestone, such as is claimed to occur at Nottingham.

Mention has already been made of the presence of a shell closely resembling *M. hausmanni* (*Aucella* of Geinitz) in the Bunter. This occurs in the sandstone, north of Salza, north-west of Langenbogen (Ebert, *loc. cit.*). The fossil is of common occurrence, and is accompanied by *Gervillia murchisoni*, the characteristic fossil of the Middle Bunter.

It seems, then, that the palæontological evidence is not opposed to the idea that the Upper Magnesian Limestone of England is contemporaneous with part of the Bunter.

---

[1] W. Waagen, 1881, p. 241.
[2] S. von Wöhrmann, 1894, p. 2.
[3] Th. Ebert, 1889, p. 241.

IV. Conclusions.

In considering the relation of the Permian and the Trias in the North of England, the nature of the junction of the Permian Middle Marl with the Bunter in South Nottinghamshire is of fundamental importance. In a previous section stratigraphical evidence has been adduced to prove that the junction is a strictly conformable one; that the Permian Marl merges imperceptibly into the Bunter above; and that, consequently, we must assume that the deposition of the Bunter commenced immediately after the Permian Middle Marl had been laid down. The evidence relied on is:

(1) An apparent perfect upward passage from the Marl to the Bunter, visible in the Great Central Railway-cutting between Annesley and Kirkby;
(2) A similar section in the Great Northern Railway near Kimberley;
(3) The fact that these cuttings are 6 miles apart shows that the apparent conformity extends over at least this distance, and is very probably, therefore, a real conformity;
(4) Other sections in brickpits, etc. showing similar relations, at intervals between Nottingham and Mansfield.

To these arguments more general ones may be added.

The thickness of the Middle Marl in South Nottinghamshire is from 10 to 20 feet, so that if there was an unconformity between it and the Bunter amounting to 1° only, the Marl would be entirely overlapped in a distance of 300 yards (taking the thickness at a maximum). It has, however, been followed continuously from Nottingham to Mansfield (a distance of 12 miles), and in the whole of that distance its apparent thickness varies by only a few feet. Outlying spurs of high ground also enable us to trace it across the strike, as from Watnall Chaworth to Bulwell (a distance of 3 miles), or from Skegby to Mansfield (a distance of 2 miles); and here again the outcrop does not show any signs of being overlapped. These facts can only be accounted for by a perfect conformity of the Permian Marl with the Bunter.

The folding map (Pl. V) shows that the Bunter and the Permian have an identical strike; whereas the Bunter and the Keuper, between which there is evidence of a slight unconformity, have slightly different strikes.

Some possible objections have already been dealt with. The absence of the Permian Marl at Mansfield, for about a mile in a north and south direction, has been shown to occur in conjunction with curious local characters in the limestone below; and a theory which explains both of these phenomena has been suggested, namely: that limestone and marl are replaced at this point by the bar of a Permian river, and that the Marl is really represented by sandrock which has been mistaken for Bunter. At Warsop, where the Marl again does not appear, the ground is overlain with alluvial deposits, and this may prove to be the explanation of the apparent absence of the Marl. On the other hand, the base of the Bunter is very marly, and its lower portion may here represent the Marl.

An explanation of the successive disappearance of the Permian subdivisions from north to south, alternative to that of unconformable overlap by the Bunter, is that each member of the

Permian is thinning southwards: the upper member disappearing first and the lowest last. There is no doubt that the Permian deposits do thin southwards, and also (as is shown by borings) westwards, as does the Trias above. The explanation is, however, insufficient to account for the facts. While the Trias as a whole thins southwards, its lower members thin northwards: it is suggestive, at the least, that as the Permian Marl and Upper Magnesian Limestone develop northwards, so does the Lower Mottled Sandstone diminish, and, after this has entirely disappeared, the Pebble Beds above lose in importance and finally disappear also, leaving the Keuper resting directly upon the fully developed 'Permian.'

The conditions of deposition of the Permian and Triassic rocks is still largely a mystery. It is, however, clear that the magnesian limestones and the Keuper were formed in a Caspian Sea, and that the Bunter is probably non-marine.[1]

The thin Permian of Nottingham, which is distinctly a littoral formation, can scarcely be the time-equivalent of the thick deposits of Durham, which consist of 800 feet of limestone. But the Marl Slate with its fossils occurs at the base of the series in both places, and therefore the upper part of the Durham Limestone is newer than any part of the Nottingham Permian, a fact corroborated by such fossil evidence as exists. Now, the Nottingham Permian was immediately followed by Bunter, so that the upper part of the Durham Magnesian Limestone is the chronological equivalent of some part of the Nottingham Bunter: that is, both are Permian or both are Trias.

We know that the early Zechstein sea had its southern limit at Nottingham, and its western limit not far to the west of the present outcrop: hence the assumption of a gentle uplift acting during Zechstein times, and causing the coast-line to migrate in a north-easterly direction, would account for Bunter being formed towards the south, perhaps by torrential floods on the flat coast-lands, contemporaneously with the continued formation of limestone off the coast. Meantime the sea-bottom was slowly subsiding in the Durham area, allowing of the formation of a thick mass of shallow-water limestone. There would, therefore, be a slowly rising area in the south and a slowly sinking area in the north; while the line about which the movement turned migrated in a north-easterly direction. It appears that, at the end of the period, the sea, always of a Caspian character, became increasingly salty. This is indicated by the poverty of the fauna and dwarfed nature of the fossils in the Upper Limestone,[2] and by the occurrence of rock-salt and gypsum in Durham, towards the end of the period. The Keuper, which followed, indicates a slight inroad of the sea, which was still, however, very salt, for dolomite, gypsum, and rock-salt occur in this series also.

It is probable that, in at least the southern half of the district, there occurred a slight check to the slow steady rise of the area, during Permian times. This is indicated by the slight unconformity between the Lower Limestone and the Middle Marl, which has

---

[1] T. G. Bonney, 1908, p. 337; and J. Lomas, 1907, p. 511.

[2] J. W. Kirkby, 1861, p. 316.

been seen at intervals between Nottingham and Tadcaster. The Marl indicates somewhat deeper water than the limestone (which at Mansfield shows reptilian footprints and ripple-marks), and the passage-bed above it is very like the Keuper Waterstones in appearance, and therefore probably had a similar origin. Now, the Waterstones seem to indicate shallower water than the Keuper Marl above: for they are composed of coarser sediment, and the beds are not only ripple-marked but even sun-cracked in places; and the Permian Marl is lithologically very like the Keuper Marl. It appears, therefore, that, after the slight depression which ended the formation of the Lower Limestone and caused the Marl to be deposited, the steady rise set in again immediately.

The close of the Permo-Bunter period was brought about by a change in these movements. In the south, the Bunter was covered by the sea, for the Keuper Waterstones were deposited in water; and there appears to be a slight unconformity between them and the Bunter. In the north, there may or may not have been a change of movement, since both Waterstones and Magnesian Limestone are shallow-water deposits. The difference between them may be merely a question of the supply of sediment, for, as was remarked above, the Waterstones contain much dolomite. All that seems necessary, therefore, to bring about the change from Permo-Bunter to Keuper conditions was the sinking of the southern area below a very shallow sea, with the consequent alteration of currents in the north. The Waterstones extend over the whole of the north-eastern basin; and slow subsidence, causing slight deepening of the water, would bring about the gradual change which caused Keuper Marl to follow the Waterstones imperceptibly. All this time, however, the sea remained of Caspian character, until, at last, the open sea found an entrance and the Rhætic beds were formed.

These considerations lead to the following correlation-table:—

South Nottinghamshire.		South Yorkshire.		Durham.
Keuper Marl.		Keuper Marl.		Salt Measures. } Keuper.
Keuper Waterstones.		Keuper Waterstones.		
Probable slight unconformity.				
Pebble Beds. Lower Mottled Sandstone (and Passage Beds.)	=	Pebble Beds. Upper Marl (local). Upper Magnesian Limestone.	=	Upper Magnesian Limestone. Middle Magnesian Limestone. Lower Magnesian Limestone.
Middle Marl.		Middle Marl.		
Lower Magnesian Limestone.		Lower Magnesian Limestone.		
Basement Beds (local).		Basement Beds (local).		Basement Beds (local).

It is to be noted that the Basement Beds are local and may not be strictly contemporaneous everywhere. Kirkby (1861, p. 317), in fact, regarded the Marl-Slate of Durham as contemporaneous with part of the Lower Magnesian Limestone of South Yorkshire.

A small unconformity, between the Magnesian Limestone and the Marl above it, is recorded by Goodchild as occurring at St. Bees Head. The succession there is so similar to that of South Nottinghamshire (showing in both alike the order:—limestone; small unconformity; followed by Marl passing upwards through beds resembling Waterstones into Bunter) that one is tempted to correlate the two, although they were formed in distinct basins.

In the Manchester district the Upper Magnesian Limestone is shown, by the fossils,[1] to be represented by red clays with only subordinate bands of limestone, and here also there is not known to be any break between these beds and the Trias above, which is said to be of Bunter type.[2]

Dr. H. T. Brown has described [3] an unconformable junction of the Trias and Permian at Swadlincote (Leicestershire), where there is 5 to 8 feet of Bunter conglomerate and sandstone resting unconformably upon 27 feet of Permian sandstone, clay, and breccia, and covered by Lower Keuper. It is evident that these thin beds cannot represent, chronologically, much of the thick Bunter and Permian deposits of other districts. The unconformity observed at Swadlincote may, therefore, be supposed to represent some part of the strata seen in the Nottingham area: if, indeed, the 'Bunter' is not really the basement-bed of the Keuper, such as may be seen at Nottingham.

Correlations of beds in distinct areas are, however, not very certain, as was pointed out by Green.[4] He remarked that deposits such as those of the Permian, formed in so many distinct basins and under changing conditions, must necessarily be totally different in different areas. He objected to the habit of designating subdivisions of the English New Red by German names. For example, there was no proof that the New Red Sandstone was the time-equivalent of the Bunter.

The question of the independence of the Permian and Triassic Systems is a wide one, and can only be settled by a consideration of the strata in other regions of the earth, as well as in Britain. The evidence from Nottinghamshire, however, is of importance, because the Nottingham district has been relied on for proof of a break between Permian and Trias, which, elsewhere in this country, has failed to bear investigation. Thus Mr. H. B. Woodward, while supporting the indivisible character of the Permo-Trias, points to Nottinghamshire as a difficulty, and writes:—

> 'Near Nottingham there is evidence of the overlap of Permian rocks by the Trias, which crosses some of its upper divisions, and finally rests on the Coal-Measures. Even here there is no positive evidence of denudation between the Permian and Bunter formations, inasmuch as the overlap by the Bunter Sandstone may have coincided with a depression of the area that took place after the Upper Permian Beds were deposited.' (1887, p. 209.)

---

[1] H. B. Geinitz, 1890, p. 539.

[2] See J. W. Gray & P. F. Kendall, 1894.

[3] 'The Permian Rocks of the Leicestershire Coal-Field' Q. J. G. S. vol. xlv (1889) pp. 1–40.

[4] A. H. Green, 1887, p. 290.

The conformability of Permian and Bunter in this district removes, therefore, the only exception to the rule, and tends to prove that in England there is a New Red Sandstone System comprising all the strata between the Carboniferous and the Jurassic Systems.

V. Summary.

1. In Nottinghamshire the Permian and the Bunter are shown to be conformable.
2. Part of the 'Bunter' of South Nottinghamshire is contemporaneous with the Upper Magnesian Limestone of North Nottinghamshire; and the 'Bunter' of South Nottinghamshire, as a whole, is contemporaneous with the upper part of the Magnesian Limestone Series of Durham.
3. An explanation of the mode of origin of the White and Red Sandstones of Mansfield is given.
4. The palæontology of the Upper Magnesian Limestone is discussed, and the evidence derivable from the fossils is shown to be not unfavourable to the view stated in 2.

VI. Bibliography.

Aveline, W. T.—'The Magnesian Limestone & New Red Sandstone in the Neighbourhood of Nottingham' Geol. Mag. dec. 2, vol. iv (1877) pp. 155–56.

Aveline, W. T.—'The Relation of the Permian to the Trias' *Ibid.* p. 380.

Aveline, W. T.—'The Geology of Parts of Nottinghamshire & Derbyshire' Mem. Geol. Surv. 2nd edit. 1879.

Aveline, W. T.—'The Geology of the County around Nottingham' Mem. Geol. Surv. 2nd ed. 1880.

Aveline, W. T.—'The Geology of Parts of Nottinghamshire, Yorkshire, & Derbyshire' Mem. Geol. Surv. 2nd edit. 1880 (No. 2).

Aveline, W. T., A. H. Green, J. R. Dakyns, J. C. Ward, & R. Russell.—'The Geology of the Carboniferous Rocks North & East of Leeds, and the Permian & Triassic Rocks about Tadcaster' Mem. Geol. Surv. 1870.

Binney, E. W.—'Sketch of the Geology of Manchester & its Vicinity' Trans. Manch. Geol. Soc. vol. i (1841) pp. 35–66.

Binney, E. W.—'On the Relation of the New Red Sandstone to the Carboniferous Strata in Lancashire & Cheshire' Q. J. G. S. vol. ii (1846) pp. 12–26.

Bonney, T. G.—'On the Evidence for Desert Conditions in the British Trias' Geol. Mag. dec. 5, vol. v (1908) pp. 337–41.

Cantrill, T. C.—'On the Occurrence of *Spirorbis*-Limestone & Thin Coals in the so-called "Permian" Rocks of Wyre Forest; with Considerations as to the Systematic Position of the "Permians" of Salopian Type' Q. J. G. S. vol. li (1895) pp. 528–548.

Chamberlin, T. C., & R. D. Salisbury.—'Geology' vol. ii (New York & London, 1906).

De Rance, C. E.—'11th Report of the British Association Committee on Underground Waters' Rep. Brit. Assoc. (Aberdeen) 1885, pp. 380–95.

Dunston, G.—'The Eastern Extension of the Midland Coalfield, & the Exploration at Southcar' Trans. Inst. Min. Eng. vol. xii (1896–97) pp. 515–24.

Durnford, H. St. J.—'Deep Boring at Barlow, near Selby' *Ibid.* vol. xxxiv (1907–1908) pp. 426–48.

Ebert, Th.—'Ueber die Art des Vorkommens & die Verbreitung von *Gervillia murchisoni* Geinitz im Mittleren Buntsandstein' Jahrb. K. Preuss. Geol. Landesanst. 1888 (1889) pp. 237–42.

Fox-Strangways, C.—'Sections along the Lancashire, Derbyshire, & East Coast Railway between Lincoln & Chesterfield' Q. J. G. S. vol. liv (1898) pp. 157–68 & pl. x.

FOX-STRANGWAYS, C.—'The Geology of the Country North & East of Harrogate' 2nd ed. Mem. Geol. Surv. 1908.

GARWOOD, E. J.—'On the Origin & Mode of Formation of the Concretions in the Magnesian Limestones of Durham' Geol. Mag. 1891, pp. 433–40 & pls. xii–xiii.

GEINITZ, H. B.—'The Dyas or Permian Formation in England' [Transl. by E. W. Binney] Trans. Manch. Geol. Soc. vol. iv (1864) pp. 121–46.

GEINITZ, H. B.—'On the Red & Variegated Marls of the Upper Dyas, near Manchester' [Transl. by Mark Stirrup] *Ibid.* vol. xx (1890) pp. 537–54.

GIBSON, W.—'On the Character of the Upper Coal-Measures of North Staffordshire, Denbighshire, South Staffordshire, & Nottinghamshire; & their Relation to the Productive Series' Q. J. G. S. vol. lvii (1901) pp. 251–66.

GIBSON, W., T. I. POCOCK, C. B. WEDD, & R. L. SHERLOCK.—'The Geology of the Southern Part of the Derbyshire & Nottinghamshire Coalfield' Mem. Geol. Surv. 1908.

GOODCHILD, J. G.—'Observations on the New Red Series of Cumberland & Westmorland, with Especial Reference to Classification' Trans. Cumberland & Westmorland Assoc. for the Advancement of Lit. & Sc. No. xvii (1891–92) pp. 1–24 & 2 pls. (reprint).

GRAY, J. W., & P. F. KENDALL.—'On the Junction of Permian & Triassic Rocks at Stockport' Rep. Brit. Assoc. (Nottingham) 1893, pp. 769–70.

GREEN, A. H.—'The Geology of Northumberland & Durham' (Review of 'Outlines of the Geology of Northumberland & Durham' by G. A. Lebour) Nature, vol. xxxvi (1887) pp. 289–90.

GREEN, A. H., & R. RUSSELL.—'The Geology of the Neighbourhood of Wakefield & Pontefract' Mem. Geol. Surv. 1879.

HICKLING, G.—'On Footprints from the Permian of Mansfield (Nottinghamshire)' Q. J. G. S. vol. lxii (1906) pp. 125–31.

HIND, WHEELTON.—'Monograph of the British Carboniferous Lamellibranchiata' pt. ii, Palæont. Soc. 1897.

HINDE, G. J.—'A Monograph of the British Fossil Sponges' Palæont. Soc. 1887–93.

HOLMES, T. V.—'The Permian, Triassic, & Liassic Rocks of the Carlisle Basin' Q. J. G. S. vol. xxxvii (1881) pp. 286–98 & pl. xi.

HOWELL, H. H.—'Note on the Classification of the Red Rocks in South-East Durham; and on a Possible Unconformity between the Trias & the Permian Limestone in the same District' Geol. Mag. dec. 3, vol. vii (1890) pp. 8–13.

HULL, E.—'The Geology of the Country around Oldham' Mem. Geol. Surv. 1864.

HULL, E.—'The Triassic & Permian Rocks of the Midland Counties of England' Mem. Geol. Surv. 1869.

HULL, E.—In 'On the Manufacture of Salt near Middlesbrough' by Sir Lowthian Bell, Proc. Inst. C. E. vol. xc (1887) pp. 131–45, &c.

HULL, E., & A. H. GREEN.—'The Geology of the Country round Stockport, Macclesfield, Congleton, & Leek' Mem. Geol. Surv. 1866.

IRVING, Rev. A.—'On the so-called "Permian" & the New Red Sandstone Formations' Geol. Mag. dec. 2, vol. iv (1877) pp. 309–12.

IRVING, Rev. A.—'On the Classification of the European Rocks known as Permian & Trias' Geol. Mag. dec. 2, vol. ix (1882) pp. 158–64, 219–23, 272–78, 316–22.

KENDALL, P. F.—'On the Brockrams of the Vale of Eden, & the Evidence they afford of an Inter-Permian Movement of the Pennine Faults' Geol. Mag. dec. 4, vol. ix (1902) pp. 510–13.

KIDSTON, R.—'Catalogue of the Palæozoic Plants in the Department of Geology & Palæontology, British Museum (Natural History)' London, 1886.

KING, W.—'A Monograph of the Permian Fossils of England' Palæont. Soc. 1850.

KIRKBY, J. W.—'On the Permian Rocks of South Yorkshire; & on their Palæontological Relations' Q. J. G. S. vol. xvii (1861) pp. 287–325 & pl. vii.

LAMPLUGH, G. W., W. GIBSON, R. L. SHERLOCK, & W. B. WRIGHT.—'The Geology of the Country between Newark & Nottingham' Mem. Geol. Surv. 1908.

LOMAS, J.—'Desert Conditions & the Origin of the British Trias' Geol. Mag. dec. 5, vol. iv (1907) pp. 511–14, 554–63.

MURCHISON, Sir RODERICK, & R. HARKNESS.—'On the Permian Rocks of the North-West of England, & their Extension into Scotland' Q. J. G. S. vol. xx (1864) pp. 144–65.

RAMSAY, Sir ANDREW.—'On the Recurrence of Certain Phenomena in Geological Time' Rep. Brit. Assoc. (Swansea) 1880, pp. 1–22.

ROEDER, C.—'Notes on the Permians & Superficial Beds at Fallowfield' pt. ii, Trans. Manch. Geol. Soc. vol. xxi (1892) pp. 104–13.

SCHIMPER, W. PH., & A. SCHENK.—In K. A. Zittel's 'Handbuch der Palaeontologie' II. Abtheil. Paläophytologie, Munich, 1890.

SEDGWICK, A.—'On the Geological Relations & Internal Structure of the Magnesian Limestone, & the Lower Portions of the New Red Sandstone Series in their Range through Nottinghamshire, Derbyshire, Yorkshire, & Durham, to the Southern Extremity of Northumberland' Trans. Geol. Soc. ser. 2, vol. iii, pt. i (1829) pp. 37–124.

SEDGWICK, A.—'On the New Red Sandstone Series in the Basin of the Eden, & North-Western Coasts of Cumberland & Lancashire' *Ibid.* vol. iv, pt. ii (1836) pp. 383–407.

SORBY, H. C.—Anniversary Address, Q. J. G. S. vol. xxxv (1879) Proc. pp. 56–95.

STEINMANN, G.—'Einführung in die Paläontologie' 2nd ed. Leipzig, 1907.

'Summary of Progress for 1903' Mem. Geol. Surv. 1904.

'Summary of Progress for 1908' Mem. Geol. Surv. 1909.

TATE, T.—'Notes on Recent Borings for Salt & Coal in the Tees District' Q. J. G. S. vol. xlviii (1892) pp. 488–95.

TEALL, J. J. H.—'The Pennine Chain' Geol. Mag. dec. 2, vol. vii (1880) pp. 92–93.

WAAGEN, W.—'Palæontologia Indica, ser. xiii, Salt Range Fossils, vol. i: *Productus* Limestone Fossils, iii. Pelecypoda' Mem. Geol. Surv. India, 1881.

WARD, J. C.—'On Beds of supposed Rothliegende Age, near Knaresborough, &c.' Q. J. G. S. vol. xxv (1869) pp. 291–97.

WILLS, L. J.—'On the Fossiliferous Lower Keuper Rocks of Worcestershire, with Descriptions of some of the Plants & Animals discovered therein' Proc. Geol. Assoc. vol. xxi (1910) pp. 249–331 & pls. x–xxvi.

WILSON, E.—'On the Permians of the North-East of England (at their Southern Margin), & their Relations to the Under- & Overlying Formations' Q. J. G. S. vol. xxxii (1876) pp. 533–37.

WILSON, E.—'The Magnesian Limestone & New Red Sandstone in the Neighbourhood of Nottingham' Geol. Mag. dec. 2, vol. iv (1877) pp. 238–240.

WILSON, E.—'On the South-Scarle Section' Q. J. G. S. vol. xxxv (1879) pp. 812–13.

WILSON, E.—'The Age of the Pennine Chain' Geol. Mag. dec. 2, vol. vii (1880) pp. 93–95.

WILSON, E.—'The Permian Formation in the North-East of England, with Special Reference to the Physical Conditions under which these Rocks were Formed' Midland Naturalist, vol. iv (1881) pp. 97–101, 121–24, 187–91, 201–208.

WILSON, E.—'On the Durham Salt-District' Q. J. G. S. vol. xliv (1888) pp. 761–782.

WÖHRMANN, Baron S. VON.—'Ueber die systematische Stellung der Trigoniden & die Abstammung der Nayaden' Jahrb. K.-k. Geol. Reichsanst. vol. xliii (1893–94) pp. 1–28.

WOODWARD, A. S.—'Outlines of Vertebrate Palæontology' London, 1898.

WOODWARD, A. S., & C. D. SHERBORN.—'A Catalogue of British Fossil Vertebrata' London, 1890.

WOODWARD, H. B.—'Remarks upon the Relations & Grouping of the Permian & Triassic Rocks' Geol. Mag. dec. 2, vol. i (1874) pp. 385–90.

WOODWARD, H. B.—'The Geology of England & Wales' 2nd ed. London, 1887.

WOOLACOTT, D.—'Preliminary Note on the Classification of the Permian of the North-East of England' Rep. Brit. Assoc. (Winnipeg) 1909, pp. 476–77.

ZITTEL, K. A. VON.—'Grundzüge der Paläontologie' Munich, 1903.

MAPS.

Geological Survey Maps. Old Series.

Sheet 71. N.W., Belper; 71. N.E., Nottingham; 82. S.W., Chesterfield; 82. S.E., Mansfield; 82. N.W., Sheffield; 82. N.E., Tickhill; 87. S.W., Barnsley; 87. S.E., Doncaster; 87. N.W., Wakefield; 87. N.E., Snaith.

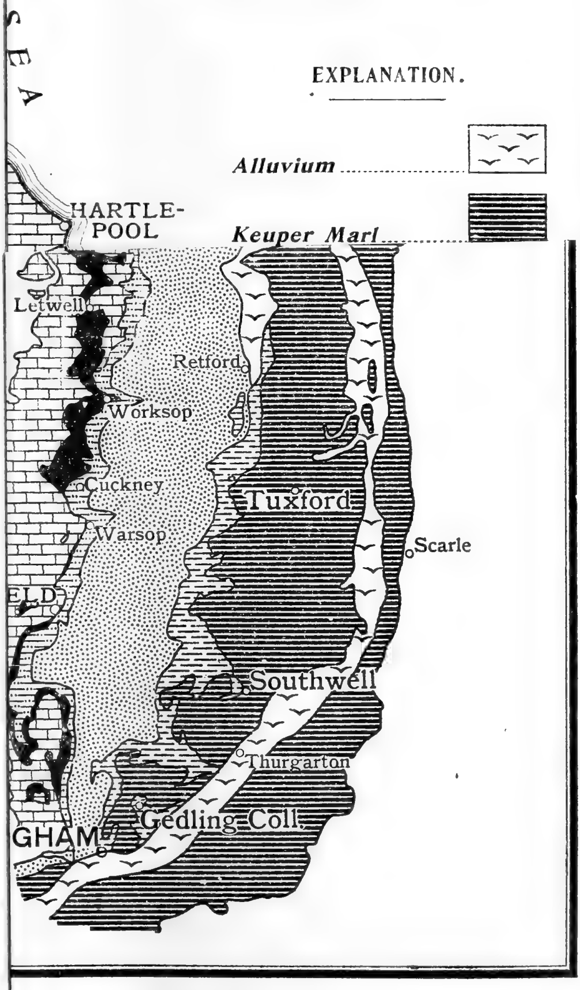
New Series.

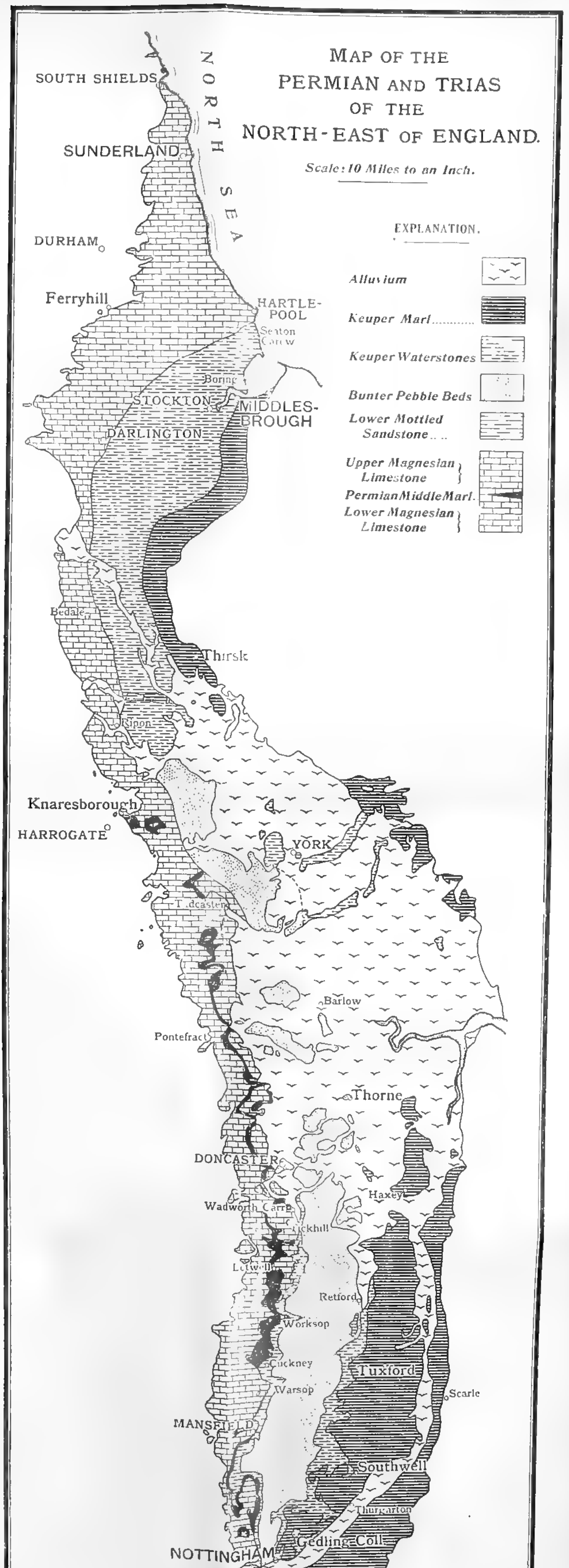
Sheet 125. Derby; 126. Nottingham; 70. Leeds; 62. Harrogate; 61. Pateley Bridge; 52. Ripon; 51. Bedale Masham; 42. Northallerton; 41. Richmond; 33. Stockton; 32. Staindrop; 27. Durham; 26. Bishop Auckland; 21. Sunderland; 15. Tynemouth.

Quart. Journ. Geol. Soc. Vol. LXVII, Pl. V.

MAP OF THE PERMIAN AND TRIAS OF THE NORTH-EAST OF ENGLAND.

Scale: 10 Miles to an Inch.





MAP OF THE PERMIAN AND TRIAS OF THE NORTH-EAST OF ENGLAND.

Scale: 10 Miles to an Inch.

EXPLANATION OF PLATE V.

Map of the Permian and Trias of the North-East of England, on the scale of 10 miles to the inch.

DISCUSSION.

Prof. BOYD DAWKINS said that he had studied the district chiefly from the point of view of water-supply. He referred to a series of borings which proved the singularly persistent eastward thickening of the Permian marls. A revision of the geological survey had been needed for many years, and he was glad that it was in such competent hands as those of the Author.

The AUTHOR, in reply, said that the information obtained from a number of deep borings to the east of the Permian outcrop was summarized in the paper. The sections showed a thickening of the Permian rocks eastwards and the passage of the Lower Magnesian Limestone into grey mudstones and shales, indicating deeper water towards the east.

3. *The* EFFECTS *of* SECULAR OSCILLATION *in* EGYPT *during the* CRETACEOUS *and* EOCENE PERIODS.[1]

By WILLIAM FRASER HUME, D.Sc., Assoc.R.C.S., Assoc.R.S.M., F.G.S., Director of the Geological Survey of Egypt. (Read November 23rd, 1910.)

[PLATE VI—GEOLOGICAL MAP.]

CONTENTS.

I. INTRODUCTION.

IN the year 1878 Prof. Zittel[2] laid the foundations of modern Egyptian sedimentary geology on a broad basis, since which period the Cretaceous and Eocene strata of that country have aroused much interest. The problems which have especially appealed to investigators are:—

(1) The age of the Nubian Sandstone.
(2) The changes of the fossiliferous Cretaceous strata when traced from north to south.
(3) The nature of the junction between the Eocene and the Cretaceous.
(4) The distribution and variation in the Eocene beds.
(5) The nature of the changes which have marked the passage from the Eocene to the Oligocene Period.

The work carried out by the Egyptian Geological Survey has, since 1896, widened our knowledge of the facts on which the broader theoretical conclusions will have to be based; and, in the present contribution, I shall endeavour to set forth the new data which have been obtained by me in connexion with each of these questions, only referring to the results of other investigators

---

[1] In view of the new facts obtained during the expedition of 1910, the author was permitted to rewrite his paper on 'The Cretaceous & Eocene Strata of Egypt,' presented to the Geological Society in 1909, so as to include these results.

[2] K. A. von Zittel, 'Ueber den geologischen Bau der Libyschen Wüste' (Festrede) K. Bayerisch. Akad. Wissensch. 1880, and 'Beiträge zur Geologie & Paläontologie der Libyschen Wüste, &c.' Palæontographica, vol. xxx, 1883.

where these are necessary to complete the consideration of areas which have not been personally investigated. The portions of Egypt which have thus come under personal study are :—

(1) Eastern Sinai.
(2) A longitudinal region bordering Wadi Qena.
(3) The area between latitudes 25° N. and 28° N. covered by the Eastern Desert Survey Memoirs of 1903 and 1906.
(4) The districts bordering the Nile between Esna and Aswan.
(5) A series of traverses across the Western Desert between the Oases of Dungul, Kurkur, Kharga, and the city of Edfu, with a brief study of the Arbain road south of Kharga.
(6) Traverses from the Nile to Baharia, embracing visits to the Moela Oasis and the Fayum.
(7) Studies in the neighbourhood of Cairo (Moqattam Hills, Abu Roash, Helwan, etc.).

Owing to results obtained during 1910, it is no longer possible, in my opinion, to treat the Nubian Sandstone and the fossiliferous Cretaceous strata as separate entities, but they should now be considered as parts of a single series. From this remark the Carboniferous sandstone and limestone present in Wadi Araba and Western Sinai must be excluded, as these contain Carboniferous fossils. As no fossils of this age have at present been noted elsewhere in Egypt, it is probable that these strata have only a limited development.

II. VARIATIONS IN THE FOSSILIFEROUS CRETACEOUS STRATA, AND THEIR RELATION TO THE NUBIAN SANDSTONE.

The gradual advance of the sea over many continental lands during the Upper Cretaceous Period is one of the best established of geological hypotheses, and Egypt contributes a striking illustration of this general tendency. The predominance of deep-water conditions in the north is witnessed by the deposition of limestones throughout the whole of Upper Cretaceous times ; only farther south is the presence of continental areas indicated by the occurrence of the well-known Nubian Sandstone, which, of relatively minor importance in Northern Egypt, in the south is the dominant member of the Cretaceous System. Several phases may be recognized, in which the organic and detrital deposits differ conspicuously as regards their distribution in time and space, marking successive stages in the gain of sea over land. The Cretaceous strata here considered consist of (1) the Danian, (2) the Campanian and Santonian divisions of the Senonian or Upper Chalk, (3) the Turonian or Middle Chalk, and (4) the Cenomanian or Lower Chalk. The French terms will be used throughout this paper.

(A) The Cretaceous Strata of Northern Egypt.

In Egypt the northernmost Cretaceous belt, extending from Southern Sinai through the Gebel Ataqa and Galala Hills to Abu Roash, with a western extension in the Baharia Oasis, is characterized by a great development of limestones during Danian, Senonian, and Turonian times.

The Cenomanian beds are also highly fossiliferous, but the strata are marls in Sinai and of a more sandy nature in the Baharia Oasis. The unfossiliferous Nubian Sandstone immediately underlies the Cenomanian, and typical sandstones nowhere reappear higher in the section. A typical succession for this Northern type is displayed in the plateau-edge of Gebel Gunna, in Eastern Sinai, as follows:—

	Thickness in metres.
(Top.) 1. Ferruginous limestones. Some of these beds contain traces of diademoid sea-urchins, and suggest a parallelism with the Lower Senonian beds near Wadi Qena subsequently described	61
2. Limestones or green marls containing *Echinobrissus humei* Fourtau, and *Cyphosoma* aff. *majus* Coq. : the presence of the latter points to these beds being still of Turonian age.	
3. Bivalve-cast limestone.	
4. *Ostrea-olisiponensis* Limestone, associated with *Ostrea rouvillei* Coq.	
5. Green marls containing *Periaster oblongus* Dunc., *Tylostoma elatius* Coq., and *Heterodiadema libycum* Cott. Also numerous sea-urchins described by Prof. J. W. Gregory[1]	3·5
6. Loose sandstone and marls, containing large specimens of *Ostrea olisiponensis* Sharpe in abundance	14
7. White grits of the Nubian Sandstone, calcareous in the upper 10 metres	200

The typical Cenomanian beds in this section have not been recognized in the Abu Roash district; but that area may still be retained in the northern division, owing to the great development of Turonian, Senonian, and Danian limestones.[2] In Baharia, on the other hand, the fossiliferous Cenomanian strata with characteristic oysters and sea-urchins are well-developed; but the Turonian and Senonian formations are not so clearly marked as elsewhere, or lie in regions more difficult of study.[3]

(B) The Cretaceous Strata of the Wadi Qena Area.

During the season of 1910, a very interesting region was explored at the head of Wadi Qena, in the Eastern Desert of Egypt—the study revealing an unexpected transitional phase, characterized by alternations of sandstones and Upper Cretaceous limestones.

---

[1] Geol. Mag. dec. 5, vol. iii (1906) pp. 216–27 & pls. x–xi.

[2] H. J. L. Beadnell, Egypt. Geol. Surv. Report (1900) pt. ii, 'The Cretaceous Region of Abu Roash,' 1902, in which reference will also be found to the work of other authors in this area.

[3] See J. Ball & H. J. L. Beadnell, Egypt. Geol. Surv. Memoir on Baharia Oasis, 1903.

Alternation of Sandstones and Upper Cretaceous Limestones.

Wadi Qena is a wide expanse, bounded on the west by the precipitous cliffs of the limestone plateau, which has its western termination in the scarps bordering the Nile Valley. On the east, in sharp contrast with the uniform flat-topped rock-wall of the limestone plateau, are the serrated and multi-coloured granitic peaks or the more monotonous greenish dioritic, volcanic, and metamorphic members of the Red Sea Hills, while between them lie broad plains, out of which rise brown tabular outliers of Nubian Sandstone.

Between the main drainage-line of Wadi Qena (which itself is relatively rich in vegetation) and the western scarp is a confused country of low hills, terminating towards the valley in a secondary well-marked cliff varying from 50 to 150 metres in height.

Until last year (1910) this country had not been geologically examined; but, although details still require elucidation, the broad features are clearly revealed. It owes its present character to a conformable succession of Cretaceous strata dipping on an average 3° westwards (varying from south-west to north-west), which are probably some 300 metres thick. They are especially well developed in the watershed region at the head of Wadi Qena, where three great drainage-systems meet, one of the sections studied being in Wadi Hemaiet, which descends from the limestone plateau to Wadi Qena, and thus to the Nile at the town of Qena; a second section in Wadi Abu Had, which, rising near the head of Um Hemaiet, descends rapidly to the Gulf of Suez; while the third section was exposed in the low hills separating Wadi Hawashia from Wadi Tarfa, the latter being a great drainage-line which joins the Nile not far from Minia.

The most important feature in these sections is the threefold repetition of strata typical of the Nubian Sandstone, between beds the fossil contents of which definitely fix their age: so that we may here speak of an Upper, a Middle, and a Lower Nubian Sandstone, the two first-named from their associations being indubitably Upper Cretaceous, while the lower division is not readily separable from the Cenomanian strata which it underlies. The most notable divisions recognized may be thus summarized:—

The highest beds of the series are displayed in the precipitous cliff-face which forms the eastern termination of the great limestone plateau east of the Nile. These were recorded as members of the Nummulitic Series by Dr. G. Schweinfurth,[1] but the ascents made on these somewhat dangerous scarps show them to be composed in their upper part of

1. A white limestone weathering to a biscuit colour, and containing broad tabular bands of flint or large isolated concretions (an example measured 60×40 cm.) of the same material. This is underlain by

---

[1] Dr. Schweinfurth has published an excellent series of topographical maps with geological notes, embracing most of the Eastern Desert north of 26° N., and issued by Dietrich Reimer, 29 Wilhelmstrasse, Berlin.

2. A white limestone of similar lithological character, but without flints. In its lower portions are isolated bands of *Ostrea vesicularis* Goldf. and numerous scattered examples of *Pecten farafrensis* Zitt. (*P. mayer-eymari* Newt.).

The presence of a *Terebratulina*, though rare, is further evidence of the Danian age of this deposit, as the form resembles the species occurring in the Danian of the Oases. Aggregates of cubical pyrite altered to limonite and stem-like concretions of iron oxide are frequently present; but, as a whole, the series is throughout of great lithological similarity, and very poor in fossils. At the extreme base of these strata is a band rich in *Ostrea vesicularis* var. *judaica*, which attains a large size.

3. Immediately beneath the *Vesicularis* Beds is a succession of grey-tinted strata, about 3 metres thick, characterized by an abundance of sharks' teeth, vertebræ, etc., especially *Otodus auriculatus* Ag. and *Corax pristodontus* Ag. Specimens brought from this bed have been analysed, and yielded over 20 per cent. of tricalcic phosphate. Associated with them are large specimens of *Plicatula*, and immediately below them comes a band containing an oyster which has affinities with *O. nicaisei*.[1] These probably correspond with the Campanian farther south.
4. Underlying these are the uppermost beds of the detrital series, consisting of well-banded green shales, alternating with beds of dark clay containing rock-salt or brown phosphate-layers, the whole resting upon flaggy sandstones.

This Upper Nubian Sandstone and Shale is of geographical importance, as it is more rapidly eroded than the Danian Limestones on the west and the Santonian Beds on the east, resulting in the production of an easily-traversed shallow depression at the heads of Wadi Hemaiet and Wadi Abu Had. A notable feature in this region is the steep local westward dip of the sandstones, angles of from 23° to 35° having been noted. Farther east the strata are horizontal, no ready explanation of these phenomena having been obtained during the time available for study.

These three divisions (2, 3, & 4) can be traced northwards to the southern scarp of the Galala Hills; but, in the low country where the great drainage-systems of Wadis Qena, Tarfa, and Hawashia have their origin, denudation of the softer members has initiated the broad valley-depressions in which they take their rise.

Owing to the rapid traverses necessitated by the waterless character of the district west of Wadi Qena, it has not been possible to make a detailed examination of the low country east of the Upper Nubian Sandstone; but, in some conspicuous ridges developed in eastward succession to this sandstone formation, a further series has been recognized, consisting of:—

5. Calcareous sandstone in slabs 2 inches thick, resting on 5 inches of yellow sands. At the base these contain ferruginous concretions, oysters of the *acutirostris* type, *Plicatula*, *Tylostoma*, and bivalve-casts, the assemblage having a strong Santonian aspect.
6. A new facies underlies these strata, a normal succession of flaggy yellow sandstones and ferruginous quartzites, typical of the Nubian

---

[1] I have to thank M. R. Fourtau for much valuable help in the identification of the oysters, sea-urchins, and ammonites obtained in the Wadi Qena area and other localities examined by me.

Sandstone, these being underlain by an alternating series of sandstones (jointed in large blocks), limestones, and thin greensand bands, the limestones containing diademoid sea-urchins (like *Rachiosoma*) and intermediate bivalves. Farther north, at the head of Wadi Abu Had and Wadi Tarfa, these strata contain enormous numbers of *Nucleolites*, in Abu Had associated with the diademoid form. Near the watershed of Tarfa and Hawashia, they immediately overlie a thick series of sandstone (flaggy, fine-grained, white varieties and red ferruginous layers alternating), which in its turn rests upon green shales. This typical Nubian succession is probably at least 50 metres thick, and *Holectypus turonensis* is found in the uppermost portion of these sandstones; in the green shales below them sharks' teeth (*Scaphorhynchus*) are present.

7. This great mass of Middle Nubian Sandstone (for there is no difference in its character from that of the typical Nubian Sandstone farther south) forms conspicuous secondary ridges to the west of Wadi Qena, and in part determines the watershed between the Hawashia and Tarfa drainages. Its age is left in no doubt, as it immediately overlies
8. The limestones rich in ammonites, which are present in vast numbers in many localities south of the Galala Hills: these ammonites, which often attain a large size, are mainly species of *Hemitissotia* and *Pseudotissotia*. Though not of great thickness, indeed rarely exceeding 2 metres, these limestones are of importance, as they have such marked Lower Turonian characteristics.
9. They immediately overlie the Cenomanian Series, already well known from the researches of Schweinfurth and Zittel; the strata appear in a series of zones, which, due to the comparatively steep dip, form a succession of broad bands, and give rise to characteristic scarps or plains. The most conspicuous of these are thick limestones, almost entirely composed of *Ostrea olisiponensis* Sharpe, and forming a well-marked low scarp wherever present. Underlying them are the following in regular succession:
10. An *Ostrea-flabellata* Zone, with *Hemiaster pseudofourneli* P. & G., *Venus reynesi* Coq., etc.
11. *Ostrea-africana* Zone, with *Neolobites fourtaui* Perv. and *N. schweinfurthi* Eck.
12. *Ostrea-suborbiculata* Zone, in which this oyster is present in vast quantities.

These Cenomanian strata form the summit of the high cliff (150 metres) which bounds Wadi Qena on the west, and immediately overlie the white friable sandstone (13), the Lower Nubian Sandstone, which is highly calcareous in its upper portion, and contains well-rounded quartz-pebbles sparsely distributed through it. The beds at the base of the cliff are lithologically very similar to those at the summit, there being no evidence that any portion of the sandstone is of earlier date than the period of the Cenomanian advance of the sea. It may, therefore, be stated with some degree of certainty that, apart from the Carboniferous sandstones of Northern Egypt and Sinai, the great mass of the Nubian Sandstone hitherto studied was formed during the Cretaceous depression, and in the Wadi Qena area was a distinct marine deposit, representing temporary increase of activity in the accumulation of detrital materials, due either to climatic or to tectonic changes.

III. THE HAMMAMA TYPE.

South of latitude 27° 15′ N. a very marked change is apparent in the character of the Cretaceous strata, the denudation which has taken place in the lower portion of Wadi Qena having, however, removed all traces of the stages in the process. In the section developed in Gebel Abu Had, 25 miles north-east of Qena, only the Danian and Campanian beds are present as fossiliferous strata, and these immediately overlie the Nubian Sandstones, in which no fossil-bearing layers have been noted. A typical section in Wadi Hammama, 25 miles east-north-east of Qena, is as follows :—

		Thickness in metres.
Top.		
DANIAN ...	1. Biscuit-coloured limestone .... 2. Green shales .. .. 3. Yellow limestones and *Pecten-farafrensis*[1] or *P. mayer-eymari* Marls	122
CAMPANIAN...	4. Hard bluish crystalline limestone with many cephalopoda (*Ptychoceras* sp., *Anisoceras* sp., and *Baculites syriacus* Conr.) : elsewhere, as near Qosseir, represented by beds with *Trigonoarca multidentata* R. B. Newton and *Ostrea villei.*	
	5. Bone-bed containing many teeth of *Otodus auriculatus* Ag., *Galeocerdo* sp.	
	6. Oyster-limestone.	

These Danian and Campanian strata, as shown in the Egyptian Geological Survey Memoir on the Eastern Desert (by T. Barron & W. F. Hume, 1902), are very widely distributed in the area between the Nile Valley and the Red Sea, from latitudes 25° to 28° N. They form part of a Cretaceous facies, which is in addition characterized by the total absence of fossiliferous Turonian and Cenomanian members.

IV. THE DANIAN EXTENSION IN EASTERN EGYPT.

A further change in Cretaceous characteristics from north to south is displayed by the Danian strata, which I have now examined over wide areas from the Southern Galala Hills to Kharga Oasis. In the region bounding Wadi Qena this series consists of a vast thickness of white chalk, which is remarkably unfossiliferous in its higher portions. Near the base are scattered individuals of *Ostrea vesicularis* Goldf., *Pecten farafrensis* Zitt. (*P. mayer-eymari*, R. B. Newt.) being also irregularly distributed. The only other fossils noted were small *Baculites* and *Terebratulina.* At the extreme base is a layer composed of a large form of *Ostrea vesicularis* var. *judaica*, which is present at times in great numbers. Very

---

[1] See M. Blanckenhorn, 'Neues zur Geologie & Paläontologie Ægyptens' Zeitschr. Deutsch. Geol. Gesellsch. vol. lii (1900) p. 411 ; and J. Wanner, Palæontographica, vol. xxx (1902) p. 114 & pl. xvii, figs. 1–3. Compare with R. B. Newton (*P. mayer-eymari*), Geol. Mag. dec. 4, vol. v (1898) p. 535.

different is the fauna of the Danian in the Western Oases, where Zittel recognized three well-marked divisions :—

(*a*) Snow-white well-bedded limestones or earthy chalk.
(*b*) Greenish and ashen-grey paper-shales.
(*c*) Beds with *Exogyra overwegi* Buch.

These beds are characterized by a fauna consisting of small gasteropoda, bivalves, corals, crinoids, etc., replaced in iron oxide, which have been made familiar to all students of this subject in the works of Quaas and Wanner, based on Zittel's collected materials. The side-issue as to the age of the *Pecten* Beds had been settled by Dr. Blanckenhorn's recognition of the *Pecten* (named *P. mayer-eymari* by Mr. R. Bullen Newton) as being identical with the *P. farafrensis* of Zittel, but certain difficulties still existed in regard to their correlation with the Danian beds of Western Egypt. Delanoue[1] had obtained a rich fauna in the grey paper-shales 31 metres thick, which underlie the Eocene limestone at Thebes, foraminifera and ostracods being abundant; while, among the larger forms, d'Archiac recognized numerous gasteropoda (*Fusus, Triton, Cerithium, Natica*), cephalopoda (*Aturia ziczac* Sow., *Nautilus centralis* Sow., and *N. delanouei* d'Archiac), dimyarian bivalves (*Nucula, Leda, Lucina, Neæra*), and brachiopoda such as *Terebratulina tenuistriata* (Leym.). This assemblage, regarded as recalling the fauna of the London Clay, led to the inclusion of the shales in the Eocene.

During his visit to Egypt, Zittel extended his researches to the eastern side of the Nile, and called attention to the importance of a layer rich in Cretaceous oysters conspicuously developed near Edfu. These he regarded as the equivalent of his *Exogyra* Beds in Kharga Oasis, etc., and remarked that, if this were the case, between it and the Lower Eocene should be a thick complex of ashen-grey or green paper-shales, and above these a white chalky limestone.

The shales were noted by him on the right shore of the Nile near Esna, where they underlay the snow-white Lower Eocene *Operculina* Limestone, Dr. Schweinfurth also noting them at the base of the Eocene escarpment on both Nile banks. Zittel remarked, however, that neither he nor Dr. Schweinfurth had been successful in finding fossils in them, adding :

> 'If these paper-shales of Esneh correspond with those of Khargeh and Dakhel, then the uppermost white Cretaceous limestone with *Ananchytes ovata* is either wanting at Esneh, or does not contain any fossils and cannot thus be distinguished from the petrographically similar Eocene limestone of the Libyan stage,'

the latter alternative being considered the more probable.[2]

---

[1] C. R. Acad. Sci. Paris, vol. lxvii (1868) pp. 704-707.

[2] 'Beiträge zur Geologie & Paläontologie der Libyschen Wüste' Palæontographica, vol. xxx, pt. i (1883) p. lxxviii. Dr. G. Schweinfurth, in Petermann's Mitteilungen, vol. xlvii (1901) p. 6, regarded the paper-shales at Esna and Sharawna as of Eocene age, following the opinion then held by most writers. See also R. Fourtau, Bull. Soc. Géol. France, ser. 3, vol. xxvii (1899) p. 481.

Dr. Blanckenhorn made a considerable advance when visiting Luxor in 1902, by finding a small fauna in the shales between the temples of Deir el Bahari and Deir el Medina, in which Dr. Oppenheim recognized thirteen species identical with those occurring in the Cretaceous beds of the Oases, including so characteristic a species as *Cinulia ptahis* (Wann.). Two species also agreed with forms from the Chalk of Siegsdorf in Southern Bavaria; and the cephalopod originally named *Aturia ziczac*, which had been so helpful in complicating the problem by its strong Eocene affinities, was regarded as really a precursor of that species and named by Oppenheim *Aturia præziczac*. Mr. Beadnell[1] later re-examined the eastern bank of the Nile, and was enabled to arrive at broad conclusions with regard to the Cretaceous age of the Esna Shales, and the relations of those beds to the White Chalk. Hitherto, however, the relations of the Oases Danian fauna to the *Pecten* Beds of the Eastern Desert had not been precisely determined. During the spring of 1905, when examining the geology of the Eastern Nile Valley border between Esna and Aswan, I was enabled to obtain satisfactory evidence of their relations and of the Upper Cretaceous succession in this portion of the country, obtaining some valuable evidence in addition to that already recorded by Mr. Beadnell (*op. cit.*, table on p. 675).

The strata in question are well exposed in the shallow valleys to the east of Kilabia, on the eastern bank of the Nile south of Esna, where the following succession is clearly displayed:—

(Top.) 1. The summits of the hills are covered with a biscuit-coloured limestone containing abundant Lower Eocene fossils, notably *Conoclypeus delanouei* de Lor., *Rhabdocidaris libyensis* Gregory, and *Linthia cavernosa* de Lor. *Operculina libyca* Schwager sometimes forms the main mass of the rock.

2. An upper series of shales, the Esna Shales, in which fossils are rare, corals similar to those mentioned below (p. 127) being, however, obtained on several occasions.

3. White Limestone or Chalk weathering pink, which contains very poor specimens of *Ostrea vesicularis*. The absence of distinctive fossils has been a cause of difficulty: and, after a most careful search by several observers, the fauna remains remarkably poor, being limited to *Echinocorys vulgaris* Leske (found by Mr. Beadnell at Fares, on the western bank of the Nile near Kom Ombo, but searched for in vain by both of us on the eastern side); *Ostrea vesicularis* (from various localities); *Ventriculites* of large size (on the shore at Ragama, Kom Ombo plain); and *Schizorhabdus libycus* (found by Dr. Schweinfurth and Mr. Beadnell near Ragama, and by myself on the summit of the white limestone in the hills west of Esna). Despite its poverty, the fauna is evidently that of the White Chalk of the Oases, and the limestone of Kilabia and Kom Ombo is therefore the Eastern equivalent of that formation.

4. Shales underlying the White Limestone.—When examining the Kilabia section, I obtained an abundant Danian fauna which is

---

[1] 'Relations of the Eocene & Cretaceous Systems in the Esna-Aswan Reach of the Nile Valley' Q. J. G. S. vol. lxi (1905) pp. 667–78.

practically identical with the series recorded from the ashen-grey paper-shales of the larger Oases, and described in the valuable works of Wanner and Quaas.[1]

LIST OF DANIAN SPECIES FROM KILABIA.

Caryosmilia granosa Wann.
Palæopsammia multiformis Wann. } Abundant.
Cyphosomoid form. Minute.
Pentacrinus sp.
Terebratula cf. *libyca.*
Terebratulina chrysalis Schloth.
Leda leia Wann. Very common.
Nucula sp. Very common.
Scalaria desertorum Wann.
Cerithium abietiforme Wann.
Avellana cretacea Quaas.
Volutolithes desertorum Quaas.
Volutolithes sp.
Fasciolaria (Odontofusus) rohlfsi.
Alaria schweinfurthi Quaas. Very common.
Alaria sp.
Nautilus desertorum Zitt.
Baculites sp.
Odontaspis sp.

This fauna is almost absolutely identical with that of the ashen-grey clays of the Southern Oases: on the other hand, there are certain differences when it is compared with the Luxor series. The comparison shows a difference as regards the corals, *Caryosmilia granosa* and *Palæopsammia multiformis* being both unrecorded at Luxor, where *Palæopsammia zitteli* Wann. and *Pattalophyllia ægyptiaca* (Wann.) take their place; the absence of *Alaria schweinfurthi*, one of the commonest of the Kilabia forms, is also a noticeable feature, while the most prominent member of the upper shales present at Luxor, the *Aturia* now named *præziczac* by Oppenheim, was sought for in vain in the district east of Esna. It is at present premature to say whether these differences are local, but the *Aturia* certainly seems to be restricted to the upper portion of the Esna Shales.

5. *Pecten* Limestones.—A second band of marly limestone underlying these ashen-grey shales is characterized by the abundance of *Pecten mayer-eymari* Newt. (*P. farafrensis* Zitt.) and presumably is equivalent to the *Pecten* Marls above-mentioned.
6. Shales similar to those of No. 4 underlie the marls, but were not well exposed where examined.
7. Cephalopod Bed.—There is evidence of the existence of this bed beneath the shales, as several species of *Scaphites* allied to *Sc. kambysis* Zitt. were found on a plateau south of the escarpment in which Beds 1 to 6 are best developed. This stratum probably is closely associated with
8. The Oyster-Bed and Phosphatic Series, which are practically the most prominent members in the lower country between Sharawna and Mahamid—the oysters having given rise to a very hard limestone, which has determined the well-marked plateau succeeding the conspicuous white hill-ranges wherein the limestones and shales are displayed. The oysters are typically Campanian, including as principal members *Ostrea forgemolli* Coq. and *O. villei.* Closely associated with the oyster-layers, and generally underlying them in the typical sections, is a phosphatic layer containing abundant fish-teeth, among which those of *Otodus biauriculatus* Zitt. are conspicuous.

---

[1] The succession obtained during my studies is here given in view of the discovery of this fauna, otherwise the results of my expedition agree very closely with those of Mr. Beadnell. The chief point on which we differ is where he regards the Esna Shales as passage-beds, his view being based on observations made in Farafra Oasis, a locality which I have not had an opportunity of studying. In his paper he does not state whether he obtained the typical small gasteropod fauna in the shales recorded above the *Operculina* Beds.

9. In many cases these lower members of the fossiliferous Cretaceous series are underlain by further greenish-coloured shales, or may be immediately succeeded by the uppermost layers of the Nubian Sandstone.

Before proceeding to consider the latter, the general conclusions as to this interesting Cretaceous series may be summarized.

Its age.—The following table shows better than words the relations of this fossiliferous series to the strata of similar age both on the west and on the north.

Oases.	Esna District.	East of Qena.
Lower Libyan Limestone.	Lower Libyan Limestone.	Lower Libyan Limestone.
Upper Shales.	Upper Esna Shales.	White marly beds. Upper Esna Beds.
White Chalk.	White Chalk.	Marly limestone.
Ashen-grey Paper-shales.	Lower Esna Shales.	Greenish shales. Lower Esna Beds.
	Pecten Marls and Shales.	White marly limestone with *Pecten*. *Ptychoceras* Bed.
Exogyra-overwegi Beds.	Cephalopod Bed. Oyster Limestone.	Coprolite Bed.
	Coprolite Bed.	Oyster Limestone.

An examination of the foregoing table shows a broad general resemblance between the series in the three localities, and there cannot be the slightest hesitation in agreeing with Mr. Beadnell, in regarding the beds from the summit of the White Chalk to the base of the *Pecten* Marls as of Danian age. Indeed, I should be inclined to admit the Upper Esna Shales into the same category, such forms as have been found in these strata resembling those of the underlying shales, and having no connexion with the beds containing the varied Eocene fauna, rich in echinoderms and Operculinæ, which immediately overlie them.

On the other hand, all writers on this subject seem to be agreed that the Cephalopod and Oyster Beds are of Campanian age, and so the controversy with regard to the Cretaceous age of the whole series appears to be settled.

The important changes noted, passing from north to south, are therefore:

(1) In the regions north of latitude 26° N., the Danian White Chalk is mainly unfossiliferous, except for scattered Pectens and oysters. The rich coralline and bivalve fauna of the Oases has never been observed, and shales are absent in the series.

(2) In contrast, the Danian Series of the Oases is composed of both shales and white limestones: these contain small corals, univalves, and bivalves, and consequently they probably indicate shallower-water conditions than are exhibited farther to the north-east, where such life as existed was micro-organic.

(3) In the neighbourhood of Esna the Western and Eastern Danian types are co-existent and closely related.

The third Cretaceous facies occupying the greater part of Southern Egypt is thus divisible into an Eastern and a Western division,

according to the nature of the Danian White Chalk and the presence or absence of shales. Its other general features are the great development of phosphatic beds in the Campanian Series and the complete dominance of sandstone during the Cenomanian and Turonian epochs, no fossiliferous strata of these ages having been recorded south of latitude 27° N. This phosphatic Cretaceous belt sweeps from the hills near Gebel Zeit in a southerly and south-westerly direction, crossing the Nile between Esna and Edfu, and reappearing in the northern portions of Kharga and Dakhla Oases.

V. The Southern Cretaceous Type.

A fourth facies was recognized during my expedition of 1908 in the extreme southern portions of Egypt: especially at the Oasis of Dungul, near Kurkur Oasis, and on the great Arbain road south of Kharga. In these regions the Danian strata are, in the main, a compact white limestone containing simple corals of the *Cœlosmilia* type, while the shales play a subordinate part. The most noticeable change is in the character of the Campanian strata, which, instead of being phosphatic or fish-bearing, are characterized by a remarkable development of small sea-urchins, large *Turritellæ*, and a great variety of univalves recalling the Red Sea fauna of the present day. They are noticeable for their marked yellowness, and are a conspicuous feature wherever observed. The sea-urchins which I collected have been recently described by M. R. Fourtau[1] under the names of *Dorocidaris chercherensis* (*op. cit.* p. 96), *Bothriopygus schweinfurthi* (from Dungul, p. 104), and *Gitolampas fallax* (from Dungul and Um Shersher, pp. 107–15), the last-named being extraordinarily abundant at Um Shersher, on the Arbain road.

VI. Summary of Cretaceous History in Egypt.

We are now able to trace the sequence of Cretaceous history in Egypt, both by modifications in the stratigraphical series and by variation in its lateral distribution. Five phases are recognizable, exclusive of those noted in Syria, where the whole of the Upper Cretaceous appears to be represented by limestone. The five phases are as follows:—

(1) The North Egyptian type, in which the whole of the beds, from the Danian to Cenomanian, are represented by limestones; while the Cenomanian marls and limestones are highly fossiliferous, *Hemiaster* sp. and various exogyroid forms of oysters being dominant. The Nubian Sandstone is, in its entirety, older than the Cenomanian.

(2) The Wadi Qena type, in which the Upper Cretaceous series is subdivided by bands of sandstone, presenting features regarded as characteristic of the Nubian Sandstone. The Danian

---

[1] 'Description des Échinides fossiles' Mém. Inst. Égypt. vol. vi, fasc. ii, December 1909.

is typically white chalk throughout, with scattered specimens of *Pecten farafrensis* (*P. mayer-eymari*) and *Ostrea vesicularis* var. *judaica* in abundance at the base. The Campanian is phosphatic. The best-marked sandstone-bands occur between the Campanian and the Santonian, immediately overlying the Turonian, and at the base of the fossiliferous Cenomanian. The Upper Nubian Sandstone beds have well-marked green and red shales associated with them.

This series may itself be subdivided into two sub-types: (*a*) the Hawashian (from Wadi Hawashia), in which ammonites of the *Tissotia* group are strongly developed in the Turonian strata; and (*b*) the Um Hemaiet sub-type, in which ammonites are absent, and the Turonian, as such, is not markedly developed.

(3) The Hammama type, so named from Wadi Hammama, in which these strata were first recorded by the late Mr. Barron and myself. This type also includes the Campanian strata which had been previously studied by Prof. E. Fraas on the Qena-Qosseir road. The characteristics are: partial replacement of Danian white chalk by the green and red Esna Shales and by *Pecten-farafrensis* (*P. mayer-eymari*) Marls, the white limestones forming inconspicuous bands. The Campanian beds are still phosphatic, but the Turonian and the Cenomanian are no longer represented, the strata of those ages in this position being sandstones, with the exception of the (bituminous) Abu Rahal *Lingula* Shales. These are at present a local occurrence, for which no parallel has been found elsewhere.

(4) The Oasis type, in which the Danian shales are rich in corals and small univalves, and the white limestone is characterized by the presence of *Echinocorys*, *Pentacrinus*, and a single coral recalling those of the White Chalk in North-Western Europe. As in No. 3, the Campanian is phosphatic, and the Nubian Sandstone commences immediately below the oyster-beds of that formation.

(5) The Dungul type, in which the Danian shales are less marked, while the hard subcrystalline limestones contain single corals widely distributed. The Campanian beds are no longer phosphatic, the corresponding strata being very rich in sea-urchins and univalves. The Nubian Sandstone commences immediately below the oyster-zone of this series.

The varying characters of the above-mentioned five types clearly illustrate the gradual advance of the sea over Egypt during Upper Cretaceous times, the invasion having commenced earlier in North-Eastern Egypt, and the transition being marked by the relative distribution of the sandstones, clays, and limestones, both in time and in space. Among the most interesting features are the faunal enrichment of the Danian limestones in the south-west, probably due to their deposition in shallower waters; the change from phosphatic conditions to abundant sea-urchin and univalve life in the same direction; the prevalence of limestone in the north, of sandstone in the south, and of an alternating series of limestones and sandstones in the centre of Egypt.

VII. TRANSITION FROM THE CRETACEOUS TO THE EOCENE PERIOD.

The gradual advance of the Cretaceous sea over the greater part of Egypt having thus been proved in a very convincing manner, we have next to enquire what were the changes which led to the remarkable dissimilarity between the Eocene and the Cretaceous faunas. Egypt has long been regarded as a striking illustration of lithological continuity, when the strata formed during the two periods are compared; but close study of the two formations reveals some suggestive differences in the relations existing between them in various parts of the country.

In the South of Egypt the junction between Eocene and Cretaceous appears in two different forms. In the first, or Luxor type, the shales containing a typical fauna of small gasteropoda, pelecypoda, etc. presenting a Danian character, are separated by only a few metres of a white chalk (weathering to a biscuit colour) from more massive Eocene limestones containing large forms of *Rhabdocidaris*, *Linthia*, and *Lucina thebaica* Zittel.

In many localities these strata are characterized by the presence of *Operculina libyca* Schwager, which sometimes forms almost the entire mass of the limestone. In such places the nature of the transition is not very evident, and the marked palæontological hiatus is not accompanied by very sharp lithological differentiation. In the limestone-plateau north-west of Qena the conditions are remarkably different. There, at the base of the cliff facing Wadi Qena on the west, are a series of fine-grained, well-stratified, chalky limestones containing *Pecten farafrensis* Zitt., *Ostrea vesicularis* Goldf., *Terebratulina* sp. (?),[1] and other typical Danian fossils. These pass, so far as can be judged, into limestones of precisely similar lithological character, yet revealing no trace of fossils; their honeycombing, close-set stratification, and jointing give them the appearance of having been formed under intense current-action rather than of having been deposited in the waters of a quiet sea. These strata are of great thickness, over 100 metres (300 to 400 feet thick), and the typical *Nummulites* of the Eocene only appear where more massive limestones overlie these softer beds.

On the north the differences become further emphasized, there being marked unconformity between the Eocene and the Cretaceous strata where these are in contact. A notable and familiar instance is the unconformable junction of the Middle Eocene beds with the Cretaceous at Abu Roash, near the Pyramids, described by Mr. Beadnell.[2] Here the *Carolia* Beds of the Upper Moqattam division of the Middle Eocene rest on the Danian limestones to the west; while near the Pyramids the Lower Moqattam (*Nummulites-gizehensis*) Beds occupy this position, suggesting overlap on a

---

[1] The *Terebratulina* needs further study.

[2] H. J. L. Beadnell, 'The Cretaceous Region of Abu Roash' 1902, Egypt. Geol. Surv. Report (1900) pp. 14–17 & pls. vii–viii.

Cretaceous insular area. Still more remarkable is the unconformity which has come under my notice in the Southern Galala Hills, where the lower slopes consist of a well-stratified series of white chalk beds weathering to a biscuit colour. Immediately overlying these was a highly fossiliferous stratum, the fauna of which has been identified by M. Fourtau as Lower Moqattam or Middle Eocene in age, so that the whole of the Libyan strata (commonly classed as Lower Eocene) are entirely absent. These beds are in their turn apparently succeeded by conformable subcrystalline limestones, which in many cases are true marbles. Only many miles away to the west, near Gebel Shaira, do these contain the slightest trace of fossils, those obtained being *Nummulites gizehensis* de la Harpe, and large specimens of *Velates schmiedeli* Chemn., present in a crystalline matrix.

Any theory of the relations between the Cretaceous and the Eocene Periods must take account of three essential factors :—

(1) The slight change in lithology, but marked difference in fossil contents exhibited in the South of Egypt.
(2) The striking resemblance in petrographical character, but difference in physical structure, suggesting current-bedding, exhibited in Central Egypt.
(3) The existence of marked unconformities between the two formations in Northern Egypt.

Incidentally, two other factors have to be considered : these are :—

(4) The prevalence of subcrystalline limestones at the summit of the Cretaceous or the base of the Eocene, where these meet ; and
(5) Volcanic activity, which is particularly well marked at the close of the Eocene Period.

We have seen that, during the Upper Cretaceous Period, there is strong evidence for the gradual advance of a wide-spreading sea over the whole of this portion of Africa, organic deposits gradually becoming preponderant over those of detrital origin. Examination of the Eocene and Cretaceous areas in the outer deserts has already revealed that the tectonic relations are not so simple as had been generally supposed, but that closer mapping will probably indicate a marked if gentle folding—the long axes of which have an eastward and westward tendency. The exact extent and magnitude of such foldings can only be determined by accurate levelling, but the Abu Roash-Moqattam anticlinal system and the Wadi-Araba anticline in the north find a counterpart farther south in the well-marked anticlines near the head of Wadi Qena, and in the hills south-east of the Qena bend of the Nile. It is a fair inference that such folds were the first cause of the great change so universally noted, the first basis of the new Tertiary world.

The anticlines or domes would give rise to islands or submarine ridges where erosion would be active, while the basins would form centres within the areas of which the denuded materials could be deposited. As the Danian limestones were widely distributed, the

first Eocene beds in the synclines would be re-assorted and current-affected rocks of the same lithological constitution; while the worn-down summits of the domes would be the surfaces upon which the new Eocene fauna of nummulites and Operculines, or in the shallower portions, of large sea-urchins and bivalves, would flourish. Should the views here stated be in accordance with the true course of history at this period, it might be possible eventually to map out the original domes and basins of the transition, and trace (just as has been done in the previous pages for the Cretaceous advance) the gradual gain of land from sea in the Eocene Period, by fold effects, in which the flexures occurring in the deepest-water area, namely, Northern Egypt, are the most pronounced, and consequently would be unconformably overlain by the youngest Eocene beds. In the shallow basins between the folds the easily denuded members would first be redeposited, and then the Eocene life would be developed in normal zonal succession according to principles which are as yet very obscure.

VIII. The Faunal History of Egypt during Eocene Times.

Offering this theoretical suggestion for consideration to explain the differing character of the strata immediately overlying the well-determined Cretaceous series, and leaving the unfossiliferous 'remade' white limestones as a problem for special study, I may next direct attention to some of the marked zonal variations observed in the stratigraphical succession during the Eocene Period. The change is at once marked by the incoming of the Tertiary foraminifera (*Operculina lybica* Schwag., *Nummulites variolarius* Lam., and *N. curvispira* Men.): the Operculines being present in vast numbers in the lowest zone, from the Nile Valley to the Southern Oases. Closely associated with these are strata rich in well-developed sea-urchins (*Conoclypeus delanouei* de Lor., *Rhabdocidaris libyensis* Greg., *Linthia cavernosa* de Lor., etc.) and large bivalves (*Lucina thebaica* Zitt.), there being among the larger invertebrates as marked a dominance of sea-urchins and oysters as in the Egyptian Cretaceous. Brachiopoda, on the other hand, are almost absent in both.

The beds forming the lowest Eocene strata in Egypt, termed 'Lower and Upper Libyan' by Zittel, are enormously developed, extending in the Nile Valley from north of Minia to the faulted belt near Kom Ombo.

In the Western Desert they extend to Dungul in lat. 23° 30′ N., and from the eastern or northern boundaries of the principal oases, namely: Kharga, Dakhla, Farafra, and Baharia. In the Eastern Desert of Egypt the Lower Libyan Series is equally developed, being an important constituent in the broad limestone-plateau which extends from the Nile and Wadi Qena and from the Galala Hills, and being also present in the faulted outliers near Qosseir.

Well-defined subdivisions of these strata are not easily determinable, owing partly to the inaccessible nature of the regions in

which the best sections are displayed, and partly to the vast areas which still remain unexplored.

Nevertheless, there are indications of three well-defined divisions in the Western Desert, as determined by my own studies, namely:—

(1) *Callianassa* or *Sismondia-logotheti* Zone, or Upper Libyan.
(2) *Ostrea-multicostata* Zone. } These constitute the 'Lower Libyan' of
(3) *Operculina-libyca* Zone. } Zittel.

Zittel divided his series into two divisions, the Upper and the Lower Libyan, using the Alveolines for the purpose. The spindle-shaped *Alveolina oblonga (?)* Schwag. and *A. frumentiformis* Schwag. mark the higher, and the spherical Alveolines the lower division.

The Libyan Series.

With regard to previous work on this subject, it may be noted that Dr. Blanckenhorn, in his 'Neues zur Geologie & Paläontologie Ægyptens,' recognized three divisions in the Lower Eocene, namely: Lower, Middle, and Upper Suessonian, but some difference of opinion has arisen with regard to the lower member, to which he has also given the name of the 'Kurkurstufe.' The type-example of these beds has unfortunately not been studied by anyone proficient in Egyptian palæontology, since Sir William Willcocks first drew attention to their existence at Gebel Garra, situated north of the Kurkur Oasis, near Aswan. The strata occur in the form of yellow clays 5 metres thick, overlying the Cretaceous paper-shales and overlain by 90 metres of Lower Eocene limestone. The fauna is of considerable interest, as described by Mayer-Eymar, including *Bothriolampas abundans* Gauth. and *Linthia lorioli* M.-E. The presence of the well-known Middle Eocene sea-urchin *Porocidaris schmiedeli* Goldf. has also been recorded from here; but, having had an opportunity of re-examining the original specimen (now in the Cairo Geological Museum) with M. Fourtau, I feel little doubt that it is the spine of a *Rhabdocidaris*. As *Operculina libyca* occurs in the same matrix, the 'Kurkurstufe' of Blanckenhorn in all probability represents the *Operculina-libyca* Zone, which seems to be the lowest member of the fossiliferous Eocene over the greater portion of Southern Egypt.

If the *Operculina-libyca* Beds and the overlying strata with *Ostrea multicostata* appear to be divisions of major significance, much importance must also be attached to the Upper Libyan division, owing to its widespread extent and special palæontological character. Zittel, as already remarked, separated these beds from those below them by the nature of the Alveolines, and Mayer-Eymar suggested that the base of the Upper Libyan should be drawn at his *Nummulites-biarritzensis* layer, which according to him seemed to occupy a constant geological position. At the typical section in the Hill of the Tombs, or Gebel Dranka, west of Assiut, this bed is above the tombs of the Kings, and at the base of a

series of strata 65 metres thick, rich in *Sismondia logotheti* Fraas, *Turritella ægyptiaca* M.-E., *T. oxycrepis* M.-E., and *Callianassa nilotica*. These strata are of wide extension, for M. Fourtau has recognized *Sismondia logotheti* and *Callianassa nilotica*, associated with an ovoid *Echinolampas* (named by him *E. humei*), in the collections made by me on the road from Dungul to Nakheil, a position in the Western Desert about the latitude of Aswan. North-east of the Baharia Oasis these beds re-appear with the ovoid forms of *Echinolampas*, but the typical *Callianassa nilotica* and *Sismondia logotheti* have not been recognized.

With regard to the broader geographical relationships during the Libyan Epoch, much study of detail is required; but, in a recent paper, M. Fourtau[1] has pointed out some features of great interest, in connexion with the distribution of the sea-urchins obtained at Minia, the *Rhabdocidaris navillei* Cott. being a typical Indian form from Hyderabad, as is also *Dictyopleurus haimei* Duncan & Sladen. He adduces reasons for believing that the Egyptian portion of the Eocene sea formed a centre of acclimatization of the Indo-Pacific species in their migration to the west, there being no affinities of this nature either with the Tunisian and Algerian fauna, or with the Northern Mediterranean basin, whether in Spain, France, or the Vicentino. He especially calls attention to the great affinity of this Upper Libyan fauna with that of the Eocene 'Kirthar Series' in India, citing as examples the close resemblance of certain species of *Conoclypeus* from Kirthar to *C. delanouei*; the *Sismondia varians* is almost a mutation of *S. polymorpha*; and among the Cassidulidæ, which are abundant in both regions, the genus *Gisopygus* has numerous representatives closely related to Indian forms of this genus. The genus *Kephrenia* appears to be descended from the Indian *Paralampas*, both being possibly derived from *Pygurostoma* of the Upper Cretaceous in Persia. These Indian affinities are, of course, of much interest and point out directions of further study; but the correspondence cannot be pressed too far, as from my collections in the extreme west of Egypt, near Baharia Oasis, M. Fourtau has identified the presence of the genus *Pseudopygaulus*, which indicates Algerian rather than Indian influence.

The Lower Eocene strata, as a whole, appear to be remarkably uniform in structure and palæontological character over the greater part of Western Egypt; while in Eastern Egypt the presence of the 'remade' white limestones introduces a problem of a very complex, if interesting character.

In the next division to be considered, the Middle Eocene, local variations are presented which suggest the differentiation of important land-masses in the western and southern portions of Egypt.

---

[1] 'Échinides de Minieh' Bull. Inst. Égypt. ser. 5, vol. ii (1908) p. 183.

The Middle Eocene.

One of the best-known sections of this formation is displayed in the Moqattam Hill above Cairo, and has been carefully studied by Fraas, Schweinfurth, Mayer-Eymar, Blanckenhorn, Fourtau, and Barron. The strata displayed in the cliff behind the citadel differ widely, the lower two-thirds consisting of snow-white limestones, while the upper red-brown series is characterized by the presence of numerous beds of detrital materials, mainly sands and clays, the organic contents of which also indicate their shallow-water origin. This marked topographical and lithological separation led Zittel to subdivide the Middle Eocene strata into the Upper and Lower Moqattam divisions, these being undoubtedly due to important geological changes.

It is now known, from further study, that to obtain an absolute definition for these divisions is very difficult, seeing that they have many points in common, and any means of distinction adopted in one locality fails when applied to the whole of the Middle Eocene deposits developed in Egypt. In the Fayum, for instance, the detailed stratigraphical labours of Mr. Beadnell[1] have made this region classical ground, and comparison of the results with those near Cairo show broad differences alike in thickness, fossil contents, and lithological character.

The Lower Moqattam Series.

This series has a great extension in Northern Egypt, the abundance and variety of its fossil contents with the especial dominance of large nummulites, *Echinolampas*, *Schizaster*, and the crab *Lobocarcinus*, bearing testimony to the continued prevalence of marine conditions throughout Northern Egypt. My recent examination (1909) of the Western Desert between the Nile, the Fayum, and Baharia Oasis has revealed a very definite system of zones, which it is well to record for comparison with the Lower Moqattam succession determined elsewhere.

The observations between the Nile Valley at Beni Suef and the Moela Oasis have brought into prominence a bed of more than local interest, which forms both the summit of the series and of an extremely level plateau in the region round the Moela and Rayan Oases. The upper portion of this bed near Moela contains a very globular variety of *Lucina pharaonum* Bell, accompanied by crustacean remains; the lower half, on the other hand, consists almost entirely of minute *Porocidaris* spines, the bryozoan *Eschara duvali* Mich., and other sea-urchin spines which M. Fourtau has recognized as belonging to *Rhabdocidaris gaillardoti* Gauth. The most characteristic feature, however, is the frequent presence of

---

[1] See Geol. Surv. Egypt Mem. on the Fayum (1905), with the discussions of the interesting vertebrate fauna by Dr. C. W. Andrews, and of the invertebrate palæontology of the district by Dr. M. Blanckenhorn.

large casts of the univalve *Gisortia*, and of species of the small sea-urchin *Sismondia*.

The *Gisortia* Bed is of considerable significance, both on account of its topographical importance and of its wide distribution. In my own expedition I obtained that large-sized member of the Conidæ (*Gisortia*) on the eastern side of the great gravel desert to the west of the Moela Oasis; and also on the western side of this expanse, in the Bahr district close to the northern edge of Baharia Oasis. Mr. Beadnell records it west of Fashn as a silicified limestone with large silicified Conidæ,[1] and Dr. Ball gives practically the same description of it, describing it as forming the plateau-rock near the great belt of sand-dunes.

In Moela it had already aroused the attention of Mayer-Eymar; but Dr. Blanckenhorn makes no allusion to any stratum of this nature in the area studied by him in detail on the eastern bank of the Nile between Helwan and Minia, nor has it been noted in the Moqattam section. It re-appears, however, in the desert between Cairo and Suez: for, not only is it mentioned in Barron's Geological Survey Memoir describing this region (1907), but under the same name as that adopted by me before I was aware that the term had been previously used by him.

Near the top of the cliff, at the well-known Gebel Genefe, near Ismailia, is a bed containing *Sismondia sæmanni* Desh. and *Gisortia gigantea* Munst., these being overlain by a coral-layer. In the plateau bordering Gebel Ataqa the upper beds again contained many *Lucinæ*, under these being the *Dendracis-conferta* Bed yielding *Sismondia sæmanni* and other echinid spines. It, in turn, overlies the *Gisortia-gigantea* Bed (Barron, *op. cit.* pp. 93, 95). In Blanckenhorn's work the nearest resemblance to this stratum is one recorded as the summit-rock of the Lower Moqattam Series (I. 5): where a yellow sandy limestone (with *Sismondia* cf. *logotheti*, *Thagastea luciani* de Lor., and a number of other species) overlies a hard white limestone with corals, as in the summit-bed of the Northern Galala and Gebel Awebed.[2] This *Dictyoconus* Bed, as he terms it, appears to have close relations to the *Gisortia* stratum.

Enough has been said to show that this white limestone is of prime importance; and, wherever recognized, this reef-formation practically marks the close of the Lower Moqattam Series.

The beds which underlie this stratum in the desert south-west of the Fayum are very variable in character. The first section examined in the cliff south-west of Beni Suef consisted of:—

(Top.) 1. The snow-white *Gisortia* Bed, at least 2 metres thick, containing small nummulites, *Eschara duvali* Mich., and broken *Porocidaris* spines.

2. Yellow-tinted cavernous limestone rich in small nummulites and *Gryphæa pharaonum* Oppenh., with, in places, large bent *Carolia*.

---

[1] J. Ball & H. J. L. Beadnell, 'Baharia Oasis' Egypt. Geol. Surv. Mem. 1903, p. 22.

[2] See M. Blanckenhorn, 'Neues zur Geologie & Paläontologie Ægyptens' Zeitschr. Deutsch. Geol. Gesellsch. vol. lii (1900) p. 445.

In descending the eastern scarp bounding the depression of Wadi Muela, the succession is seen to be as follows:—

1. Siliceous, cavernous limestone, with the globulose *Lucina pharaonum* Bell, and crustaceans. This is Mayer-Eymar's I. *d*, in which he also records *Gisortia*, *Rostellaria*, and *Eschara duvali* Mich.
2. White chalky limestone, made up of *Porocidaris* spines, and containing flints. (Apparently not recognized by previous writers.)
3. Greyish-yellow marls with *Gryphæa pharaonum* Oppenh.: rich, not only in that species, but also in *Spondylus ægyptiacus* R. B. Newton, *Velates schmiedeli* Chem., and the large species of *Echinolampas*.
4. Marls with *Pecten moelehensis* M.-E. and *Vulsella chamiformis* M.-E. Small nummulites are present throughout the series.
5. Clays with gypsum, probably 6 metres thick, and, so far as personal observation goes, without fossils, overlying
6. The *Nummulites-gizehensis* Beds, forming the floor of the valley. These west of Moela contain very large Nautili and *Exogyra fraasi* M.-E.

Some 40 kilometres to the westward the beds No. 3 were of especial interest, owing to the great abundance of the smaller sea-urchins, which include *Echinolampas crameri* de Lor., *Thylechinus libycus* Fourt., *Mistechinus mayeri* de Lor., etc.[1] In addition, *Exogyra fraasi* M.-E. is very abundant, also the small nummulites, and a few specimens of *Carolia*, *Solarium*, *Plicatula polymorpha* (rare). It will be seen that in these Lower Moqattam Beds the Upper Moqattam fauna is already clearly indicated, so that the upper line of demarcation is not sharply marked.

As regards the lower line of demarcation, Dr. Blanckenhorn, in his 'Neues zur Geologie & Paläontologie Ægyptens' (p. 422), states that, on the eastern side of the Nile, there is a transition from the underlying Upper Libyan Beds of the Lower Eocene to the Lower Moqattam Series. The former is to a large extent characterized by the presence of *Alveolina*; but he found in Wadi Telat Yusef, 24 kilometres east-south-east of Fashn, *Alveolina* cf. *oblonga* d'Orb., associated with *Nummulites gizehensis*, *N. lamarcki*, and his species *N. porosa*. In general, however, there is a sharp distinction between the Middle and the Lower Eocene, the main points being:—

(i) The upper beds of the Lower Eocene are characterized by *Alveolina*, while the lower beds of the Middle Eocene are characterized by the large nummulites of which *Nummulites gizehensis* is the type.
(ii) The Middle Eocene is distinguished by the larger forms of the sea-urchin *Echinolampas* (*E. fraasi*, etc.), the species of this genus in the Libyan Beds being smaller and less widely distributed.
(iii) The *Conoclypeus delanouei* de Lor., on the other hand, characteristic of the Libyan Beds, is rarely represented in the Middle Eocene.
(iv) The Moqattam Series is especially marked by the large size of the oysters (*Ostrea fraasi*, etc.) and the genus *Carolia*. In the Libyan Beds oyster-layers are often abundant, but in general these are relatively small (*O. multicostata* Desh., etc.).
(v) In the Middle Eocene siliceous concretions are comparatively rare, flinty concretions being only marked in the *Gisortia* Beds; in the Lower Eocene silicification has proceeded on a large scale, beds of flinty concretions forming conspicuous features throughout the series.

---

[1] R. Fourtau, 'Description des Echinides fossiles, &c.' Mém. Inst. Égypt. vol. vi, fasc. ii (December, 1909) p. 171.

As regards this lower division of the Middle Eocene, the evidence points to a general similarity of marine conditions at its commencement, the *Nummulites-gizehensis* Beds being developed within my own experience at such widely-separated localities as the desert west of Moela Oasis, Gebel Shaira (60 miles east of Beni Suef), and the well-known exposures at the Pyramids and in the Moqattam Hills. Its upper members, however, commence to show those local variations which make a study of the higher Eocene formations much more complicated than that of the Lower Eocene or Cretaceous conditions.

A striking example of this variation is present in the immediate neighbourhood of Cairo. When tracing the Upper Moqattam Beds along the western border of the Nile Valley from the Pyramids to Wasta, the most persistent member was a stratum rich in *Carolia placunoides* Cantr. and *Plicatula polymorpha* Bell, which served as a useful guide. Below it follows the remarkable series of unfossiliferous impure limestones and marls, in which the famous tombs at Sakkara have been excavated, and to which I have consequently given the name of the Sakkara Limestones. These only contain numerous worm-tubes and rare casts of a *Lucina*. Comparison with the highly fossiliferous strata of the Moqattam Hills (in which sea-urchins are especially abundant) and with the corresponding beds in the Fayum Series bears evidence as to the local variability in character. Farther south-west, at the extreme western edge of the Fayum, the changes become still more conspicuous, detrital materials almost entirely replacing the fossiliferous members between the *Nummulites-gizehensis* Zone and the Upper Beds containing *Carolia placunoides* and *Ostrea fraasi*. The cliff at this point, probably 100 metres high, is (except for an overhanging ledge near the summit containing the above mentioned *Carolia* and *Ostrea*) entirely composed of green clays, spotted sands, and striped clays.

South-east of the Fayum, in the hill of Der el Gahannem, the detrital materials play a most important part, a saliferous clay rich in *Ostrea fraasi*, *Carolia placunoides*, and various species of *Turritella*, being 20 metres thick. Below it is a series of sands forming a striking vertical cliff, estimated as 40 metres high. In the upper part are isolated blocks composed of nummulites, suggesting unconformity between the true Upper Moqattam Beds and the underlying fossiliferous strata rich in nummulites, from which they are separated by a thick series of sands, showing remarkable current-bedding.

This question of unconformity between the strata referred to the Upper and to the Lower Moqattam respectively was urged by Barron in his Memoir on the Cairo-Suez region, and the facts so far observed tend to enhance its significance.

Farther south the Upper Moqattam Beds give rise to a steep scarp overlooking the broad plain formed by the *Nummulites-gizehensis* Series. Here a highly fossiliferous layer forms a hard cap at the summit of the cliff, the succession being (in descending order) as follows :—

1. Bed entirely composed of oysters (*O. fraasi* M.-E., *O. reili* Fraas) 2. *Carolia-placunoides* layer with *Turritella* casts	4 metres.
3. Very fossiliferous shelly layer, with *Ostrea reili*, trochoid shells, *Turritellæ*, scattered *Carolia* 4. Beds of shell-fragments, mainly small oysters, with *Balanus*.	4 metres.
5. Beds of huge oysters about	1 metre.
6. Bed of *Ostrea reili*.	
7. Yellow sands	8 metres.
8. Yellow sands with white concretions and vertebræ of *Zeuglodon*.	

In the plain at the base *Nummulites gizehensis* was present.

If the *Nummulites-gizehensis* Beds be synchronous throughout Egypt, then these detrital deposits are the equivalents of the highly fossiliferous limestones of the Moqattam Series and the unfossiliferous limestones of the Sakkara Series, showing the enormous local variations occurring during the greater part of the Lower Moqattam epoch.

The Upper Moqattam Series.

Attention has already been directed to the marked lithological variation in the beds forming the basal and summit layers of the Moqattam Hill above Cairo, which led to the separation of the Middle Eocene into two divisions. It is probable that any attempt to separate the Upper from the Lower Moqattam Beds throughout Egypt will not be successful, as the unconformity between them is not, in any case, of an extensive character. Nevertheless, there are certain features in which the typical Upper Moqattam Beds differ in a marked degree from the Lower Moqattam division.

One of the most significant of these is the distribution of the nummulites, a point which arrests attention when a number of isolated sections are examined being that, while nummulites of various species, especially *Nummulites beaumonti*, and the small *N. schweinfurthi*, are extremely common up to a certain level, they cease very abruptly; the beds above them, often brownish-yellow, though containing many fossils present in the nummulitiferous strata, show no traces of the presence of these foraminifera. In general there need be no hesitation in referring these non-nummulitic beds to the Upper Moqattam Series. Unfortunately, it is difficult to draw the base-line of this division, because certain species which have been commonly regarded as typical Upper Moqattam forms also occur in the nummulitiferous beds. Among these we may especially note *Echinolampas crameri* de Lor., *Anisaster gibberulus* Mich., and *Ostrea clot-beyi* Bell.

This feature (namely, the absence of nummulites in the Upper Moqattam), noted in the Moqattam area, in the Fayum, and near the Pyramids, is widespread in its distribution. In the desert to the south of the gravel-covered plain, or 'Serir,' lying between Moela and Baharia Oases, and especially in the broken region known as El Bahr, reappear thick strata, characterized by the abundance of their fossil contents, their brown-red coloration, the rapidity

with which they are being denuded, and the absence of nummulites, which, occurring in thousands at the base of the hills formed by these beds, are totally absent in the layers forming their lower slopes. This abrupt change is initiated by a brown bed in which *Turritellæ* (of the *angulata* type) occur in immense abundance, above them being a series of strata in which *Ostrea fraasi* and *Carolia* attain an exceptional size.

After careful comparison of these exposures with those already known to me in the Nile Valley, I conclude that the salient characters of the Upper Moqattam Beds, viewed as a whole, are :—

(*a*) The exceptional abundance of beds of *Carolia placunoides* and *Ostrea fraasi*.

(*b*) The association of *Plicatula polymorpha* Bell in large numbers with the *Carolia*. This association is a constant feature from near the Pyramids to Baharia, and therefore this occurrence is of more than local significance. In the Lower Moqattam this *Plicatula* is present, but within my experience only as isolated individuals. Dr. Ball informs me that he found a similar association near the Red Sea, due east of Cairo.

(*c*) The general absence of nummulites.

(*d*) At times an exceptional development of species of *Turritella*, especially at the base of the series.

(*e*) The dominance of *Echinolampas crameri* and *Anisaster gibberulus* when conditions are favourable to the presence of sea-urchins.

Further study will probably indicate a triple division of the Middle Eocene as being the most convenient; the Middle Moqattam Beds in such a case would be characterized by the abundance of the *Exogyra-fraasi* bands, and a great development of the smaller nummulites (*Nummulites schweinfurthi*, *N. beaumonti*, etc.). The following synopsis shows the boundaries of these divisions, as compared with previous classifications :—

	Schweinfurth.	*Mayer-Eymar.*	*Blanckenhorn.*	Fayum (*Beadnell*).	*Hume* (north of Baharia Oasis).
UPPER MOQATTAM.	AAA and	*b* to *e*.	II. 4 to 8.	Qasr-el-Sagha Beds. (*Carolia* Beds.)	Non-Nummulitic *Carolia* Beds.
MIDDLE MOQATTAM.	AAA and AAA 1.	*a*	II. 1 to 3.	Birket-el-Qurun Beds.	Small Nummulites and *Exogyra* Beds.
LOWER MOQATTAM.	AA, etc.	I *e*, *u*, etc.	I.	Wadi Rayan and Ravine Beds.	*Gisortia* Limestone. *Gryphæa-pharaonum* Beds. *Nummulites-gizehensis* Beds.

I have purposely refrained from comparing these strata more closely with the Eocene formations of Europe, as this would require a more careful palæontological analysis than time has permitted me to undertake. Only such a study will finally decide whether the Upper Moqattam as above defined should be regarded as Upper Eocene, instead of being considered, as it was originally, the uppermost member of the Middle Eocene.

The Calcareous Grits.

The final stages in the history of this passage from the widespread Eocene sea to the Oligocene continental conditions are witnessed by the calcareous grits, which underlie the pebble-gravels forming the surface of much of the Western Desert of Egypt between the Fayum and Baharia Oasis. In these the individual rounded sand-grains are cemented in a calcareous paste. A typical section of this Calcareous Grit series was studied in the Gebel Hadahid scarp, where it is crossed by the main road from the Fayum to Baharia. The succession is as follows, the beds dipping 5° northwards :—

	Thickness in metres.
1. Quartz-chert pebble-gravels (forming the summit) ...	5·0
2. Sandy limestone (composed of fossil fragments)	2·5
3. Friable consolidated sands	15·5
4. Very false-bedded sands (calcareous)..................	3·0
5. Yellow clayey sands	1·6
6. Sandy shales (very friable) with solid yellow sandy concretions	0·8
7. Yellow clayey sands	4·0
Total	32·4

Below these in the valley is a *Lucina*-cast bed, overlying a sandy layer with scattered *Turritella* and *Cardita*. This unfossiliferous series is not of purely local occurrence, for it reappears from under the pebble-gravels to the north of Baharia, forming conspicuous cliffs and the very marked hill to which the name of Had el Bahr was given, which is composed of complex sandy grits. The same beds were again observed at only 3 kilometres from the north-western edge of the Baharia scarp.

Though not actually traced step by step into the series so clearly described by Mr. Beadnell in the 'Topography & Geology of the Fayum Province' (Mem. Egypt. Geol. Surv. 1905), these strata must represent his Fluvio-Marine division, and (judging from p. 63 of that memoir) probably that portion which has been classed with the Upper Eocene. A similar calcareous grit frequently rises through the gravel-beds, and may be regarded as Oligocene; these strata, therefore, appear to be of considerable importance, not only as regards their palæontological interest in connexion with the occurrence of *Arsinoitherium*, etc., but also on account of their wide distribution in the Libyan Desert.

The succession in the El Bahr region north of Baharia Oasis

is practically an epitome of the most typical sequence of the Eocene and Oligocene strata observed in North-Western Egypt, a dip of 5° at this locality bringing up the whole of the Middle Eocene strata within a limited area as follows:—

		Thickness in metres.	
1.	Sandy limestone with chert cap	29	Probably Oligocene.
2.	Sandy limestones		
3.	Beds containing *Ostrea fraasi, Carolia placunoides,* and *Plicatula polymorpha,* without nummulites	15	Upper Moqattam.
4.	Brown *Turritella* Beds		
5.	Strata with small nummulites and *Ostrea fraasi*	...	Middle Moqattam.
6.	*Ostrea clot-beyi* Beds		
7.	*Gisortia* Limestone	...	Lower Moqattam.
8.	Yellow limestone (*Gryphæa-pharaonum* Zone).		
9.	*Nummulites-gizehensis* Series		
10.	*Gisopygus* Beds	...	Upper Libyan.

The term Moqattam Beds, introduced by Zittel, has become so well established in the literature that it does not seem advisable to add a new name to the terminology; but a triple division of this formation seems necessary, in order to bring out the very important change marked by the disappearance of the nummulites. This triple division can be traced in all the important areas hitherto studied (see Table, p. 141).

IX. General Summary.

The main points to which reference has been made in this paper may be summarized as follows:—

A.—1. There was a gradual advance of the Cretaceous sea over Egypt during Cenomanian to Danian times, from north or north-east, five stages in this advance being indicated by the relations of the detrital Nubian Sandstone to the organic Cretaceous limestones. These phases are:—

(*a*) The Northern Egyptian type, extending from Sinai to Baharia Oasis, in which the Nubian Sandstone underlies fossiliferous marls of Cenomanian age, while limestones were forming during the remainder of the Upper Cretaceous Period (Turonian, Senonian, and Danian). The Cenomanian beds contain characteristic sea-urchins (*Hemiaster* of the *cubicus* type, etc.) and oysters (*Ostrea olisiponensis, O. suborbiculata, O. flabellata,* etc.). A minor facies is the Baharian (Baharia Oasis), in which a *Cidaris-thomasi* Bed is exceptionally developed at the close of the Cenomanian. At Abu Roash, on the other hand, the Turonian strata attain a thickness not elsewhere observed in Egypt.

(*b*) The Wadi Qena type was recognized during my recent expedition (1910) in the upper reaches of Wadis Qena, Tarfa, and Hawashia. The characteristic feature is the alternation of Nubian Sandstones with fossiliferous Cretaceous strata. At least three typical sandstone-bands are present: (1) an Upper

Nubian at the base of the Campanian; (2) a Middle Nubian above the Turonian ammonite-bed; and (3) a Lower Nubian below the Cenomanian strata and closely related to them.

(*c*) A Central Egyptian or Hammama type, extending in the Eastern Desert and on the Nile between latitudes 25° N. and 26° N. In this phase the Cenomanian and Turonian strata are absent, the Nubian Sandstone forming the greater portion of the Cretaceous System, with Santonian oysters (*O. boucheroni*, *O. bourguignati*) in its highest beds. The overlying Campanian Series is characterized by the abundance of *Ostrea villei*, *Trigonoarca multidentata*, and by phosphatic beds with *Otodus auriculatus*. The Danian member has an eastern facies, in which *Pecten* Marls are the principal feature, and a western (the Oasis type), where a fauna of small gasteropoda, species of *Echinocorys*, crinoids, and *Terebratulina* cf. *gracilis*, occurring in a chalky limestone, indicate a close affinity to the White Chalk of Northern Europe.

(*d*) A South Egyptian Cretaceous type has close resemblances to the Central Egyptian; but in the Campanian the phosphatic beds are inconspicuous, and the fauna consists of a group of small sea-urchins (mostly new species) and of gasteropoda, among which large *Turritellæ* are prominent. This facies is developed at Dungul Oasis and in the Cretaceous exposures on the Arbain road, south of Kharga Oasis.

2. The Danian fauna of the oases (small gasteropoda and corals) has been found east of the Nile near Esna in close relation to the *Pecten* Marls, the Oases and Hammama types being thus linked together.

3. As a result of the Wadi Qena expedition of this year (1910), the foregoing facts bear the strongest testimony to the Cretaceous age of the Nubian Sandstone.

B.—Regarding the transition from the Eocene to the Cretaceous, we note:—

4. The existence of two different types of strata at the base of the Eocene, the first, or Luxor type, being characterized by the abundance of *Operculina libyca*, large sea-urchins (*Rhabdocidaris*, etc.), and bivalves (*Lucina thebaica*), almost immediately overlying shales with the small Cretaceous (Danian) fauna; the second, or Qena type, being, on the other hand, entirely unfossiliferous and composed of white limestones having the closest lithological resemblance to the typical Danian white chalk with *Pecten farafrensis* or *P. mayer-eymari*, etc.

5. Though lithologically resembling the Danian limestones, those of the Qena type, which underlie strata of proved Eocene age (containing *Nummulites variolarius* and *N. curvispira*), are remarkably jointed or honeycombed, and very susceptible to denudation, as shown by the numerous caves, natural bridges, and cylindrical pipes formed in them.

As an explanation of these differences, it is suggested that these

Lower Eocene deposits represent the first evidence of the reversion in the secular oscillation, the land gaining on the sea, and being accompanied by folding. The new Eocene fauna flourished on the worn surfaces of the shallow arches, while the denuded Cretaceous material was deposited in the deeper basins.

6. As the Cretaceous beds in the North of Egypt were deeper beneath the sea at the close of the Cretaceous Period, they only became exposed late in Eocene times, thus accounting for the strong unconformities between the Cretaceous and the Eocene (mainly Middle Eocene) strata noted in Northern Egypt.

7. The above explanation would account for (*a*) the slight change in lithology, accompanied by the marked difference in fossil contents; (*b*) the striking resemblance in petrographical character, but difference of physical structure, in the biscuit-coloured limestones of Eastern Egypt; and (*c*) the presence of strong unconformities between the two formations in Northern Egypt. The origin of the crystalline limestones is still too much wrapped in obscurity for a definite opinion on this subject to be given.

8. Palæontologically, there are the usual well-marked differences between the faunas of the uppermost Cretaceous and the lowest Eocene deposits—great groups, especially the Ammonites, entirely disappearing at the close of the Cretaceous; while the Nummulites and *Operculina* appear in vast numbers in the earliest strata of Eocene age.

9. Though this great change be of prime importance, yet both periods bear a strong mutual resemblance in the dominance of oysters and sea-urchins over the other classes of animals.

10. A notable feature is the extreme rarity of the Brachiopoda in Egypt throughout Eocene and Cretaceous time; as a point of interest, apart from the general question under consideration, it may also be noted that no Belemnites, so far as I am aware, have ever been recorded from the Egyptian Cretaceous.

C.—With regard to the distribution and variation of the Eocene beds, we may note:—

11. The apparent uniformity of the fossiliferous Lower Eocene beds wherever developed in Southern Egypt; the triple zonation into Upper Libyan, or *Callianassa-nilotica* Zone, and Lower Libyan, including the *Ostrea-multicostata* and *Operculina-libyca* Zones; *Conoclypeus delanouei*, *Lucina thebaica*, and various species of *Alveolina* are, in addition, among the more characteristic forms.

12. In the Middle Eocene this uniformity is replaced by differentiation, only the lowest, or *Nummulites-gizehensis* Zone, being traceable throughout the whole area where these beds are exposed. Comparison of the sections in the well-known regions of the Fayum and the Moqattam Hill with the Western Desert area specially described in this paper reveal how great are the variations, both lithological and palæontological.

In the desert between Baharia, Moela, and the Fayum Oases, three major zones have been recognized in the Lower Moqattam

Series of the Middle Eocene: namely, from the base, (*α*) *Nummulites-gizehensis* Zone, (*β*) *Gryphœa-pharaonum* Zone, and (*γ*) *Gisortia* Limestone, the last-named being also of far wider extent and importance than had hitherto been suspected.

13. In the Upper Moqattam division of the Middle Eocene the *Turritella* Beds near the base, and the strata containing *Carolia placunoides* and *Plicatula polymorpha*, are of wide range; beds of detrital materials become of much importance; and nummulites cease to form part of the fauna.

14. The increasing importance of the detrital materials is shown by the Calcareous Grits, which have a wide extension in the North-Western Desert of Egypt, but differ in character from the mammaliferous beds of the Fayum, which are conspicuous by their brilliant colouring and by their sandy character. Their precise age-relations are uncertain, as they have hitherto not yielded fossil remains of decisive age.

15. The quartz-chert gravels forming the surface of the highest desert between Baharia and the Fayum are unconformable to the Calcareous Grits, though closely related to them as regards distribution, the suggestion that they are of Oligocene age being based on Dr. Blanckenhorn's analysis of certain freshwater shells obtained in them by Mr. Beadnell. The rounded character of the quartz-and-chert gravel and the presence of fossil wood bear witness, in conjunction with the occurrence of great land-mammals, to the incoming of continental conditions at the close of the Eocene Period.

16. This continental phase is accompanied by many indications of volcanic activity, for to this period belong the dolerites of Baharia, various basaltic occurrences in the Western Desert, the Fayum, and at the well-known quarries of Abu Zabel, near Cairo. Interesting examples of a similar nature have been recorded from the Eastern Desert, one of the latest of these being some remarkable intrusions through the Danian and Eocene rocks which I observed at the head of Wadi Um Hemaiet, near Wadi Qena.

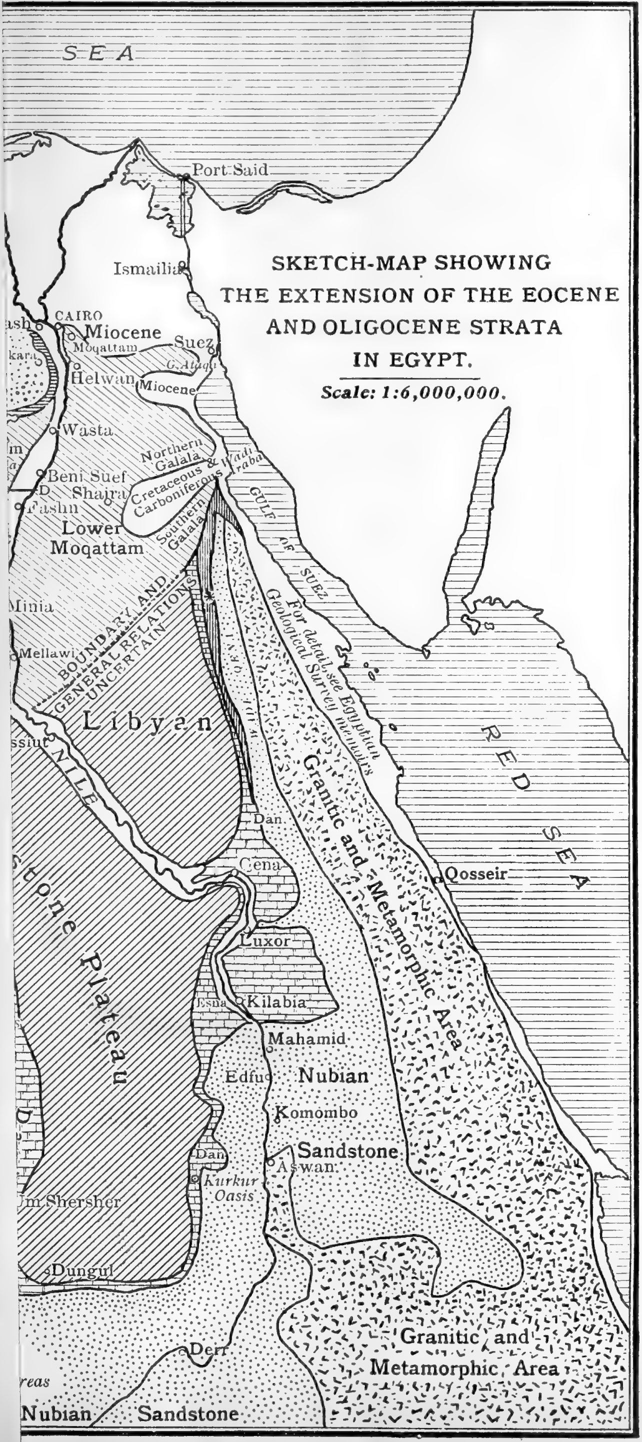
The Cretaceous Period in Egypt is, therefore, one in the main marked by the gain of sea over land; during the Eocene, on the contrary, the land appears to have been steadily gaining on the sea, probably concurrently with gentle fold-movements, which account for the minor differences in the nature of the Eocene deposits. At the close of Eocene times, and during the Oligocene Period, the approach of a continental phase is clearly indicated.

EXPLANATION OF PLATE VI.

Sketch-map, on the scale of 1 : 6,000,000, showing the extension of the Eocene and Oligocene strata in Egypt.

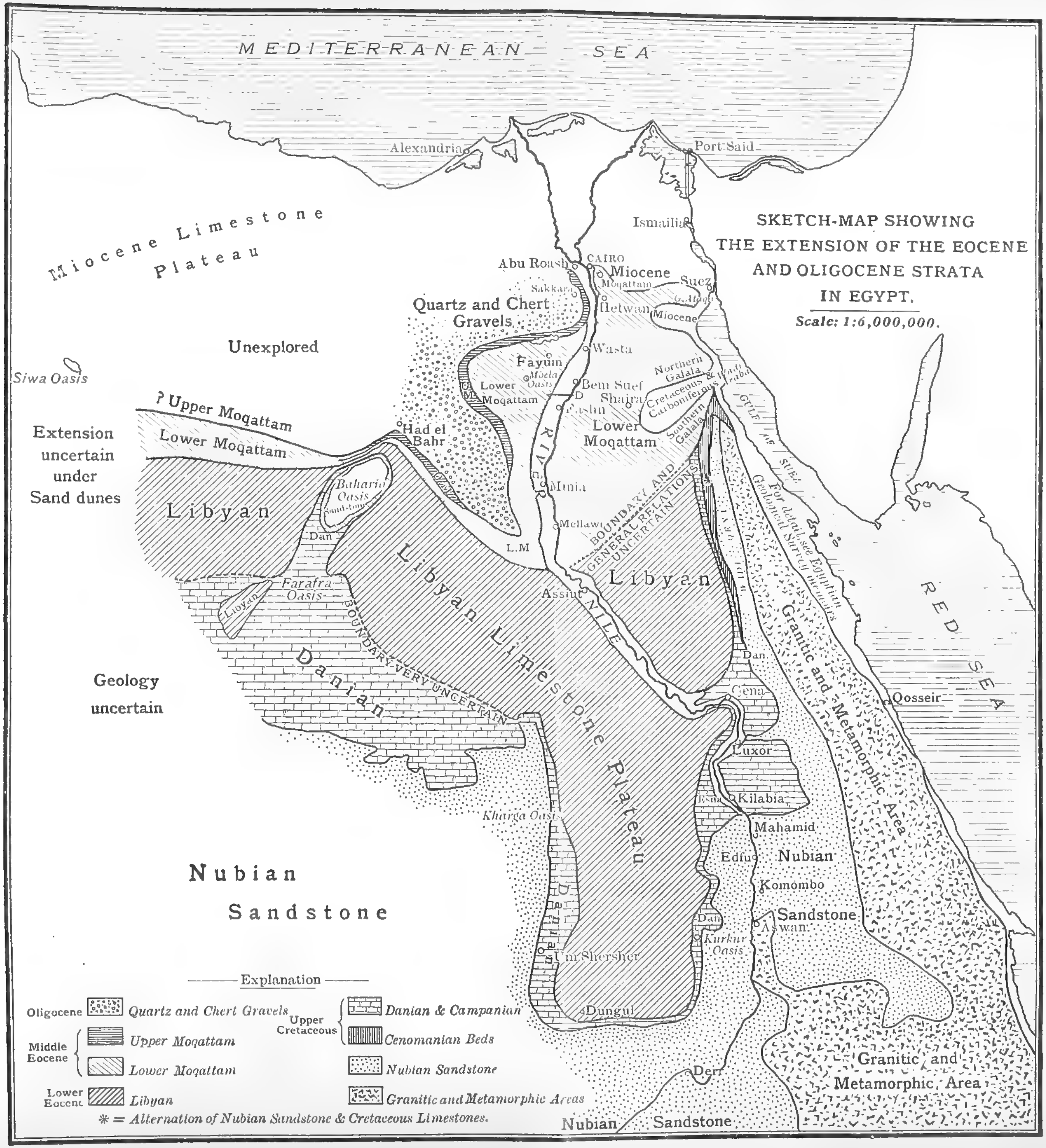
DISCUSSION.

Mr. A. WADE said that, so far as his personal knowledge of the geology of Egypt was concerned, he was in agreement with the conclusions drawn by the Author. The correlation of the almost



SKETCH-MAP SHOWING
THE EXTENSION OF THE EOCENE
AND OLIGOCENE STRATA
IN EGYPT.

Scale: 1:6,000,000.


SKETCH-MAP SHOWING
THE EXTENSION OF THE EOCENE
AND OLIGOCENE STRATA
IN EGYPT.
Scale: 1:6,000,000.
MEDITERRANEAN SEA
Alexandria
Port Said
Ismailia
CAIRO
Abu Roash
Miocene
Moqattam
Suez
Sakkara
Helwan
G. Ataqa
Miocene
Quartz and Chert Gravels
Miocene Limestone Plateau
Unexplored
Siwa Oasis
Wasta
Fayum
Moela Oasis
Lower Moqattam
Beni Suef
Shaira
Northern Galala
Cretaceous & Carboniferous
Wadi Araba
Fashn
Lower Moqattam
Southern Galala
GULF OF SUEZ
? Upper Moqattam
Lower Moqattam
Extension uncertain under Sand dunes
Had el Bahr
RIVER
Minia
Mellawi
BOUNDARY AND GENERAL RELATIONS UNCERTAIN
Bahariya Oasis
Sandstone
Libyan
Dan
L.M
Libyan Limestone Plateau
Libyan
Farafra Oasis
Libyan
BOUNDARY VERY UNCERTAIN
Assiut
NILE
For details see Egyptian Geological Survey memoirs
Granitic and Metamorphic Area
RED SEA
Geology uncertain
Danian
Dan
Qena
Qosseir
Luxor
Kilabia
Esna
Kharga Oasis
Mahamid
Edfu
Nubian
Komombo
Nubian Sandstone
Danian
Dan
Sandstone
Aswan
Kurkur Oasis
Um Shersher
Dungul
Granitic and Metamorphic Area
Derr
Nubian Sandstone
Explanation
Oligocene
Quartz and Chert Gravels
Middle Eocene
Upper Moqattam
Lower Moqattam
Lower Eocene
Libyan
Upper Cretaceous
Danian & Campanian
Cenomanian Beds
Nubian Sandstone
Granitic and Metamorphic Areas
✻ = Alternation of Nubian Sandstone & Cretaceous Limestones.

unfossiliferous biscuit-coloured limestone of the Eastern Desert with fossiliferous beds of Eocene age in the Western region was interesting. He had found fragments of sea-urchins which seemed to confirm the Author's theory as to the detrital origin of the Eastern facies. He referred the Author to an early statement made by him that the gypsum deposits of the Red Sea area were altered Cretaceous, and asked him how he accounted for the fact that, in places noted by the speaker in the Eastern Desert region, the 'biscuit-coloured limestones' apparently crop out from under the gypsum series.

Dr. **Falconer** said that he was interested to find in the paper the suggestion of a possible unconformity between the Cretaceous and the Eocene. In Northern Nigeria, where he had had an opportunity of working, there was a decided unconformity between the Cretaceous and the Eocene, and he was inclined to believe that the break at the close of the Cretaceous Period would ultimately be found to have been more or less general throughout the Sudan.

With regard to the photographs illustrating æolian erosion, he asked the Author whether or not he believed with Walther that the formation of the cliffs and escarpments, as well as the sculpture of their surface, should be assigned to the action of the wind. Similar features in Nigeria were more readily explicable on the assumption of fluviatile erosion.

Dr. A. P. **Young** welcomed the discovery of evidence clearly indicating the relations of the Nubian Sandstone to definite stages of the Lower and Middle Cretaceous. The range of the Nubian Sandstone in depth seemed still to require elucidation. On account of the easy solubility of the carbonate in both fresh and salt water, the speaker was inclined to question the probability of an important series of limestones being formed by mechanical transportation of material derived from an older source.

Dr. J. W. **Evans** enquired whether the Author had made any comparison between the Cretaceous and Eocene of Egypt and the strata of presumably similar age in Cyprus.

Dr. A. S. **Woodward** referred to the fossil eel and fossil sole exhibited by the Author from the Eocene of Tura, and remarked on the extremely close resemblance between these fishes and their existing representatives.

Mr. A. E. **Kitson** was interested to find that the Author had proved in Southern Egypt a gradual transition from the Cretaceous to the Eocene. He himself had found in Southern Nigeria, between the Niger and the Cross Rivers, that fossiliferous Cretaceous beds, having a slight west-north-westerly dip, appeared to show a gradual transition from marine, through estuarine and lacustrine, into possibly fluvio-lacustrine deposits. These were unconformably overlain by Tertiary sands. Nearer to the Niger, and west of that river, freshwater deposits with beds of brown coal occurred; while in other districts there were marine limestones, sandstones, shales, and clays. Both groups were fossiliferous, normally almost horizontal, and were probably of Eocene age. Field-evidence suggested no marked

unconformity, even if any, between the freshwater Cretaceous and the freshwater Tertiary.

Dr. Falconer had spoken of an unconformity between Eocene and Cretaceous rocks in Northern Nigeria. But would that necessarily imply an unconformity between Eocene and Cretaceous in French territory to the west of Northern Nigeria, or in Southern Nigeria? Might there not have been, in some parts of the great Cretaceo-Eocene basin or group of smaller basins that formerly existed in Northern Africa, a transition from marine Cretaceous to marine Eocene, as in Southern Egypt, or from lacustro-estuarine Cretaceous to a similar group in the Eocene? Differential movement of the land-surface could cause in local areas alternations between sedimentation and erosion, with considerable or intense folding and faulting in one area and little or none in another.

The AUTHOR, in reply, said that the precipices in Egypt were due in many cases to direct erosion by water, acting during very short periods with exceptional violence. In other instances, where great thicknesses of Eocene limestone rested upon soft shales, the latter yielded under the pressure, causing masses of limestone to be broken off, and thus leaving new precipice faces.

Erosion by fresh and salt water was naturally very important, the point being that the 'remade' biscuit-coloured limestones showed the effects of such erosion in a much higher degree than was the case with the true Danian limestones underlying them.

The opinion as to the Cretaceous and Eocene age of the gypsum at Jemsa should be still considered *sub judice*, no definite evidence being available. Undoubtedly there were large deposits of gypsum of very varied ages in Egypt, from the Pliocene downwards; and each of these had to be considered on its own merits.

The Author further said that he had not visited Cyprus, and the question of the origin of the crystalline limestones there, as well as of those in Egypt, was one of the most difficult under consideration at the present time.

In reply to a question put by Mr. Whitaker, the Author remarked that there were undoubted differences in the Nubian Sandstone, green shales being more abundant in its upper portion. The strata alternating with the fossiliferous Cretaceous beds near Wadi Qena would, if found elsewhere, be unhesitatingly regarded as true Nubian Sandstone.

The Author thanked Dr. Smith Woodward for his remarks on the Egyptian Eocene fishes exhibited, and pointed out that they were kindly presented to the Cairo Geological Museum by Mr. Crawley, head of the Technical Department in Cairo, who also supplied notes as to their supposed source of origin.

With regard to the general question of conformity and unconformity, the results obtained required caution in deduction, the Eocene and Cretaceous in the south showing more evidence of conformity than was the case in the north. Nevertheless, throughout Egypt the palæontological break was great, so far as the Author's experience went.

4. *On a* COLLECTION *of* INSECT-REMAINS *from the* SOUTH WALES COALFIELD. By HERBERT BOLTON, F.R.S.E., F.G.S., Curator of the Bristol Natural History Museum. (Read January 11th, 1911.)

[PLATES VII–X.]

CONTENTS.

I. INTRODUCTION.

I AM indebted to the courtesy of the Director of H.M. Geological Survey, for the opportunity of examining and describing an interesting suite of blattoid remains obtained by the officers of that Survey from the South Wales Coalfield.

Insect-remains of Carboniferous age are so rare in this country that the finding of no less than nine specimens, three of them with their counterparts, constitutes an event of considerable palæontological interest. The South Wales Coalfield has thus yielded more examples and more species than all other British coalfields together. All the specimens, with one exception, are blattoid in character.

The total number of fossil cockroaches known from the Carboniferous is now great, and nearly all the numerous genera and species are founded upon the anterior wings or tegmina alone. Only once in this country, so far as I am aware, have larval stages been recognized.[1]

The number of specimens and of species recorded from the British Coal Measures is singularly small, the great bulk of known forms occurring in Continental and North American coalfields. Dr. Henry Woodward,[2] in quoting S. H. Scudder's[3] census of blattoid forms, mentions 14 genera and 69 species as recorded from all Carboniferous sources.

He also mentions that Miall & Denny[4] quote Scudder as recording the number of Palæoblattariæ at 70 species. Scudder was followed by Dr. E. H. Sellards,[5] who took a broad survey of the whole

---

[1] H. Woodward, 'On the Discovery of the Larval Stage of a Cockroach, *Ettoblattina peachii*' Geol. Mag. dec. iii, vol. iv (1887) p. 433.

[2] 'Some New British Carboniferous Cockroaches' *Ibid.* p. 49.

[3] 'Palæozoic Cockroaches: a Complete Revision of the Species of both Worlds, with an Essay towards their Classification' Mem. Boston Soc. Nat. Hist. vol. iii, pt. 1 (1879) pp. 23–134 & pls. ii–vi.

[4] 'Structure & Life-History of the Cockroach, *Periplaneta orientalis*' London, 1886, 8vo.

[5] 'Study of the Structure of Palæozoic Cockroaches, with Descriptions of New Forms from the Coal Measures' Amer. Journ. Sci. ser. 4, vol. xviii (1904) pp. 113–34, 213–27 & pl.

subject, describing the structure of Palæozoic cockroaches with remarkable detail, and adding eight new species and one genus. Dr. Sellards was fortunate in securing several remarkably good forms, which he figured and described.

Still more recently, Dr. Anton Handlirsch[1] has subjected the whole of the American forms to a critical examination and revision, and has modified to a considerable extent the work of Scudder and Sellards, more especially that of the former. According to Dr. Handlirsch, the Palæozoic cockroaches, all of which he groups under the order Blattoidea, number close upon 74 genera and 271 species. About 70 of these species cannot as yet be referred with certainty to any known genus. The genera are divided into nine families.

The British forms at present known are comparatively few, and are as follows, arranged in order of their date of publication:—

ETOBLATTINA (BLATTIDIUM) MANTIDIOIDES (Goldenberg) ('Fauna Saræpontana Fossilis' 1877, p. 20).

J. W. Kirkby, 'Remains of Insects from the Coal Measures of Durham' Geol. Mag. vol. iv (1867) pp. 388–90 & pl. xvii, figs. 6–7. ('Portions of the fore-wing or tegmina [*sic*] of an Orthopterous insect nearly allied to *Blatta*, from the Coal Measures opposite Claxheugh, near Sunderland,' referred to *Blattidium mantidioides.*) S. H. Scudder, Mem. Bost. Soc. Nat. Hist. vol. iii, pt. 1 (1879) pp. 72–73, woodcut, subsequently transferred the species from Goldenberg's genus *Blattidium* to *Etoblattina.*

ETOBLATTINA JOHNSONI H. Woodw. 1887.

LITHOMYLACRIS KIRKBYI H. Woodw. 1887.

LEPTOBLATTINA EXILIS H. Woodw. 1887.

Dr. Henry Woodward[2] described the foregoing new species in 1887 from four examples, three of which had been obtained from the clay-ironstone band between the 'Brooch' and the 'Thick Coal' at Coseley near Dudley: they were all preserved in nodules of ironstone. The fourth specimen had been obtained by the late James W. Kirkby from the Upper Coal Measures, near Methil on the Fifeshire coast. This specimen is the *Lithomylacris kirkbyi* of the above list.

ETOBLATTINA PEACHII H. Woodw. 1887.

In the 'Geological Magazine' for the same year (p. 433), Dr. Woodward described the occurrence of the larval stage of a new species, which had been found in a light brown nodule of clay-ironstone obtained at Kilmaurs (Ayrshire).

---

[1] 'Revision of American Palæozoic Insects' [Transl. L. P. Bush] Proc. U.S. Nat. Mus. vol. xxix (1906) pp. 661–820.

[2] 'Some New British Carboniferous Cockroaches' Geol. Mag. dec. iii, vol. iv (1887) pp. 49 *et seqq.*

FOUQUEA CAMBRENSIS Allen, 1901.

Two previous occurrences of insect-wings are recorded from the South Wales Coalfield. Mr. H. A. Allen [1] described and figured a wing found in shale overlying the 4-foot seam in the Lower Coal Measures of Llanbradach Colliery (Cardiff), to which he gave the name of *Fouquea cambrensis.* The genus *Fouquea*, to which Mr. Allen referred his specimen, was created by Charles Brongniart,[2] who pointed out its close agreement with *Lithomantis* in the neuration, while it greatly differs in its reticulation, the nervules being so numerous as to anastomose and form a complex network.

ARCHIMYLACRIS (ETOBLATTINA) WOODWARDI Bolton (1910).

In the early part of 1910 I described [3] a new species of cockroach, *Archimylacris* (*Etoblattina*) *woodwardi*, from a tegmen found by Mr. David Davies, F.G.S., in dark blue shale overlying the No. 2 Rhondda coal-seam at Clydach Vale. Both these horizons are represented in the collection obtained by the Geological Survey.

II. GEOLOGICAL HORIZONS.

The specimens now to be described are nine in number, and have been obtained from the Mynyddislwyn Vein, the Swansea 4-foot seam, the Graigola Seam, and the well-known Rhondda No. 2 Seam. The Mynyddislwyn Vein is a noted house-coal, and is taken by the Geological Survey as the base of the Upper Series of Coal Measures.[4] It is generally correlated with the Llantwit No. 3, the 4-foot or Maesmawr Seam, and the Bedwas Vein.

The officers of the Geological Survey regard the Wernffraith or 4-foot Seam of Swansea as the equivalent of the Mynyddislwyn Vein of Monmouthshire; but by some authorities the Graigola seam is believed to correspond to that vein.[5] In accordance with the former view, the Swansea 4-foot Seam (under a variety of names, such as Llanelly 6-foot, Box Big Vein, Primrose Seam, and Broad Oak Vein) forms the base of the Upper Series in the Swansea district, just as the Mynyddislwyn Vein does in the Monmouth area.[6]

The Graigola or 6-foot Vein lies 250 yards below the Swansea 4-foot Seam, and is therefore, according to the Survey classification, in the Pennant Series. The Rhondda No. 2 Seam occurs at the base of the Pennant Series.

If we take the Geological Surveyors' view of the correlation

---

[1] Geol. Mag dec. iv, vol. viii (1901) pp. 65–68.

[2] 'Recherches pour servir à l'Histoire des Insectes fossiles des Temps primaires' St. Étienne, 1893, p. 372.

[3] Geol. Mag. dec. v, vol. vii, pp 147–51 & pl. xv.

[4] 'Geology of the Country around Newport' Mem. Geol. Surv. 1909, p. 76.

[5] 'Geology of the Country around Swansea' Mem. Geol. Surv. 1907, pp. 34, 35.

[6] *Ibid.* pp. 33, 35, 104.

of the Mynyddislwyn and Swansea 4-foot Seams as correct, it follows that of the nine specimens obtained, six came from the Mynyddislwyn horizon at the base of the Upper Series. Two specimens have been obtained from shales associated with the Graigola Seam, and a 22-inch seam 40 yards below it; while one specimen comes from shales near the Rhondda No. 2 Seam, and therefore on the same horizon as the example of *Etoblattina* (*Archimylacris*) *woodwardi* Bolton, already described by me.[1]

It thus appears that the whole of the insect-remains are referable to three horizons, one at the base of the Upper Series, and two in the upper part of the Pennant Series. The specimens, the register-numbers of which in the books of the Geological Survey are 24501, 24502, 24503, 24504, 24505, 24506, 24507, 24508, all come from the Mynyddislwyn Vein; 24501–24503 having been obtained from the Gellideg level, and 24504–24508 from the Gwernau level, both in Monmouthshire, near Maes-y-cwmmer. No. 24510 is from the 4-foot Seam of Swansea, and therefore, as supposed, on the Mynyddislwyn Vein horizon. Nos. 24511 and 24512 are from shales associated with the Graigola Seam, and a 22-inch seam 40 yards below it; while 24509 is from the No. 2 Rhondda Seam.

III. DESCRIPTION OF THE SPECIMENS.

ARCHIMYLACRIS sp. indet. (Pl. VII, fig. 2.) [Reg. No. 24508.]

Impression of the basal portion of the left tegmen. A good portion of the base is hidden; the anal area is either concealed under a large pronotal shield or is absent; and two-thirds of the distal part of the wing are also gone. This is all the more to be regretted, because of the presence of a detached pronotum, which will be described later.

The sub-costal area is strap-shaped, the vein running parallel to a very slightly curved outer wing-margin. The vein is thin, much less robust than the adjacent radius, and gives off a single branch low down, which passes obliquely forward, forking just before reaching the margin. The main stem of the sub-costa also forks at the same level, and sends two large branches to the distal end of the sub-costal area. Only the main stem and its terminal forks can be seen in the photograph. The radial vein, while stronger than the sub-costal, is less so than the median vein, and its branches are correspondingly feeble. Three branches, all directed outwards, can be distinguished, and all follow the same oblique direction as those of the sub-costa. Whether the radius reached the tip of the wing, it is of course impossible to say, but the obliquity of the veins renders this very likely.

The media is small, and branches high up, near the middle of the wing. Only faint traces of two branches are discernible near

---

[1] Geol. Mag. dec. v, vol. vii (1910) p. 147.

the broken edge. The course of these vein-fragments indicates that the marginal area of the median was confined to the apex of the wing.

The cubitus is a strong vein. Four backwardly directed branches are distinguishable, beyond which the main stem continues outwards in an almost straight line. The branches have the same obliquity to the margin, but in a direction opposite to those of the scapula. A raised line some distance out from the base, at its lower end touching the pronotum, may represent a basal branch of the cubitus or may lie in the anal area. It is doubtful whether it can belong to the anal area, as its course is perfectly straight and fairly parallel to the branches of the cubitus. I am inclined to regard it as a basal branch of the cubitus, and to think that its present position is due to fracture of the wing, and subsequent displacement.

It is impossible to form any idea of the length or breadth of the wing, so little is preserved, the total length of the fragment being only 10 millimetres. This fragment has been broken along the line of the median vein, and a portion of the wing is missing. I have already alluded to a possible displaced portion of the cubitus. The wing-surface was destitute of wrinkles, and the interspaces between the veins slightly convex (concave in the cast).

Affinities.—The general characters of the branching of the veins, and the strap-shaped sub-costal area are, I think, sufficient to justify the classification of the specimen with *Archimylacris*. Specific determination of so small a fragment is impossible.

Horizon.—Mynyddislwyn Vein, Gellideg Level, near Maes-y-cwmmer (Monmouthshire).

Associated with the impression of the fragmentary wing No. 24508 is a pronotum wholly unlike that of any blattoid known to me. It is in actual contact with the base of the impression, and lies with the dorsal side uppermost. It consists of a raised axial division, convex from side to side, and narrowest anteriorly. It appears to swell out backwards, assuming a somewhat pyriform shape. The sides are plate-like expansions, semilunar in outline, and with a very slightly convex dorsal surface, the convexity being greatest over the inner concave portion of the plate, and dying out on the free margin. The front portion of the axial division has been broken away, and there is nothing to indicate whether a rostral prolongation was present or not. The hinder central portion is also missing, and rising up out of the stony matrix filling the gap are the edges of two coriaceous body-segments. The central axial portion of the plate is black, while the lateral expansions have the colour of the matrix. Both sides preserve traces of the superficial texture, the left side being far the best in that respect. The surface is finely wrinkled longitudinally, the wrinkles gathering strength and becoming crowded together at the inner angles of the lateral plates. At the base of the left side are a few very small areas of a rich ochre colour spotted with black. The inner lower angle of the left side is rounded inwards, suggesting that the

raised median portion was incurved and shorter than the sides. The whole outer margin was thickened.

Affinities.—The appearance presented by this pronotum somewhat suggests the prothoracic shield with wing-like expansions of *Lithomantis carbonarius*.[1] The resemblance to that species is little more than superficial: for, while in Dr. Woodward's species the lateral lobes are veined like the wings, in this case there is no trace of veins, the surface being covered with longitudinal wrinkles, nor is there any clear evidence of a rostral prolongation. On the other hand, the recent Mantidæ and *Lithomantis* seem alone to possess this form of prothoracic shield, so far as I have been able to determine. Certainly it is not present in any fossil member of the blattoids, nor have I seen anything suggestive of it among the pronota of recent cockroaches. If the pronotal shield were of an undoubted mantid type, one would naturally turn again to the wing-impression, expecting to find its blattoid determination erroneous. The fact, however, that the two central main veins throw off their branches in opposite directions effectually disposes of any possibility of affinities with *Lithomantis*. That the prothoracic shield is that of a *Lithomantis* or allied form, which has been accidentally preserved in close contact with the wing of a blattoid, seems hardly likely. I am more inclined to think that the pronotal shield and the wing-fragment are parts of the same insect, and that future discoveries in older rocks may indicate that the apparent Lithomantid appearance of the pronotum points to a common origin for the blattoids and the mantids.

HEMIMYLACRIS OBTUSA, sp. nov. (Pl. X, figs. 4 & 5.) [Reg. No. 24510.]

A stout, obtuse, rounded right wing, 23 millimetres long and 14 broad. The wing lies in a soft fire-clay full of Stigmarian rootlets, and is distorted by pressure. It has been fractured obliquely across the lower third and along the anal furrow.

The outer margin is well rounded, the inner, judging by the course of the anal veins, being almost straight. The proximal half of the sub-costal area is smooth, broadly triangular, and 11 millimetres long. The sub-costa is sunken, and passes in a straight line from near the middle of the wing-base to the outer margin, forking into two short branches just before reaching the latter. On its outer side it gives off near the base two short branches, the outermost of which forks once, and the inner twice, before reaching the margin. Owing to the perfectly straight course followed by the veins, the sub-costal area is long, nearly equal to two-thirds of the length of the wing in fact, and separable into a basal smooth area, and a distal one crossed by few veins.

The radius is large, much divided, and reaches distally almost to the apical point. The lower half is characterized by a regular

---

[1] H. Woodward, Q. J. G. S. vol. xxxii (1876) pp. 60–65 & pl. ix, fig. 1.

dichotomy. Arising from the middle of the base, the vein stands out in relief for a very short distance, after which it becomes and continues sunken. Its general course is arcuated forward to the middle of the wing, after which it bends a little inwards, and then again outwards in the marginal veins of the innermost branch. It divides into two equal branches at a distance of about 6 millimetres from the base, and these divide again at the same level 3 mm. beyond the first division. Of the four branches thus produced, the outermost passes straight outwards towards the margin and parallel to the main stem of the sub-costa. It appears to die out before reaching the margin. The inner branch of this bifurcation passes staight out to the margin, giving off two smaller veins on its outer side which also reach the margin, all the three marginal veins being parallel to the sub-costa. The inner branch, which forks at the same level, also possesses two dissimilar veins, the outer agreeing in character with the adjacent vein of the outer branch; that is, it continues straight out to the margin, giving off two lateral veins on its outer side. All these branches of the radius pursue a straight course. The innermost gives off two simple branches passing out to the apex of the wing, and then forks, the outer of the two resultant veins forking again. The course of the marginal branch-veins of the radius is such that the radial area must have extended over almost the whole of the anterior third of the wing-tip.

The median vein is sunken along its whole length, and apparently continuous with the cubitus at its base. The crumpling which the base of the wing has undergone prevents accurate determination. Appearances suggest that the cubitus first divides at the top of the lower third of the wing, giving off a backwardly directed branch which forks twice at least before reaching the hinder apical margin. In all probability, the branch sends five or six veins out to the wing-margin. Near the middle of the wing, two more inwardly directed veins are given off, the innermost continuing unbranched to the broken edge of the wing, and the other forking before the edge is reached. The vein then continues almost straight out to near the apical point. The marginal portion of the median area extends from the wing-apex, or a little in front of it, to the inner border, of which it forms the distal portion.

The cubitus has little if any share in the tip of the wing. The cubitus is strongly curved inwards. It bifurcates soon after leaving the media, the inner branch vein passing outwards and inwards without division to a little distance above the middle of the hinder margin. The more central branch-vein soon forks again into two fairly equal divisions, the outer median one breaking up into four marginal veins, and the inner into three. The marginal extent of the cubitus includes the distal third of the inner wing-margin. All the veins are sunken.

The anal area is large, broadly triangular, and convex dorsally. It is marked off by a strong arcuate furrow, the anal vein standing out in relief. The subordinate anal veins are very numerous. They consist of (1) a short stem, which sends off a simple inner

branch to the margin, and then bifurcates twice, the resultant four veins pursuing a course parallel to the simple members of the main stem, and filling up the space between it and the anal furrow; (2) of a series of seven or eight straight veins, only three of which possess a single bifurcation. Not less than fourteen anal veins impinge upon the wing-margin. The base of the anal area is prolonged into a short, stout, subacute pedicle, presenting all the features of an articular surface. The wing, considered as a whole, is leathery in texture, and there is an entire absence of cross-veins or wrinkles.

Affinities.—The essential features of this wing are its broad and shortened character, the triangular sub-costal area, doubly-branched radius, the backwardly directed branches of the media, and the large anal area. This assemblage of characters is only to be found in one family, that of the Mylacridæ. The somewhat radial character of some of the anal veins, the backwardly directed branches of the media, and the long anal area limit the specimen to the genus *Hemimylacris*. In this genus also the inner division of the radius is much the largest, and covers most of the radial area, a feature in which the specimen here described agrees. I have, therefore, no hesitation in classing it as belonging to *Hemimylacris*. It is a broader wing than *H. ramificata*, and the greater humeral area is destitute of veins, while the marginal extension of the cubital area is not so large, and the general course of those veins more arcuate. It is, however, a closely related species, to which I would give the name *Hemimylacris obtusa*.

Horizon.—Four-Foot Seam of Swansea, Gladys Colliery. 1 mile east-south-east of Penller-gaer Church (Glamorganshire).

HEMIMYLACRIS CONVEXA, sp. nov. (Pl. VII, fig. 3.) [Reg. No. 24512.]

Proximal half of a tegmen, much distorted and crumpled at the base. The part remaining does not exceed 10 millimetres in length. The sub-costal lobe has been broken and crushed in upon itself: it was apparently smooth. Very little is left of the sub-costal area, which appears to have been triangular, and to have run out upon the margin at about the level of the tip of the anal furrow. Traces of two marginal veins are present.

The radius arises in the middle of the base, and almost immediately bifurcates. The outer branch divides again into two marginal veins, while the inner first sends off a long simple vein, then passes straight outwards in the direction of the apical point of the wing, bifurcating just before the broken edge of the wing is reached. While the fragmentary marginal branches of the sub-costa appear curved, those of the radius are straight. The intervening areas are flat in both cases.

A comparatively wide interspace divides the radius from the media. It is scarcely possible to separate the latter vein from the cubitus with certainty, so little of the wing being present. I am

inclined to regard the single vein shown next to the radius, as the basal end of a comparatively small media. This vein-stem shows a bifurcation at the end of the middle third of its visible length, and a second bifurcation on the outer branch near the broken edge of the wing. It is difficult to determine whether the next inner long simple vein belongs to the media or not. It approaches the base of the media very closely indeed, but, as I believe, does not fuse with it. The crumpling of the wing at the critical point prevents positive determination either way.

The next inner vein is a part or the whole of the cubitus. I interpret it as the lower or inner division, regarding the long vein previously noted as the outer branch of the cubitus. The inner division consists of a stem gently arcuated, and bifurcating twice, ending on the middle third of the inner margin in four branches. The anal furrow follows a course parallel to the inner branch of the cubitus. The wing has broken along the course of the furrow, and thus obscured its characters somewhat. It can be determined, however, that the furrow is shallow and the vein thin. The anal area is crossed by three small veins arising from one basal point, and radiating outwards to the margin. Owing to the fracture, the anal area has become a little displaced inwards.

Affinities.—Owing to the fragmentary and crumpled condition of the wing, the affinities are by no means easy of determination. By far the most important features determinable are the almost equal sub-costal and anal areas, the restriction of the radial area to the outer half of the wing-apex, and the corresponding expansion of the median veins over the inner half. The few anal veins distinguishable seem to radiate from one point. All these are features characteristic of the family Mylacridæ of Scudder. The generic relationships are clearly those of Handlirsch's genus *Hemimylacris*, and the correspondence with the lower half of that author's *Hemimylacris ramificata* is remarkably close. Differences there are, but of specific value only. I may instance the few anal veins in the South Wales fragment, and the clear suggestion of an almost straight inner margin. Careful comparison with the characters of *Etoblattina*, *Gerablattina*, and *Archimylacris* have satisfied me that it can be none of these, and I therefore place the specimen in the genus *Hemimylacris* of Handlirsch.

Although the full characters of the wing cannot be determined, it seems desirable to give the species a name, as it is clearly not *H. ramificata*. I assign to it, therefore, the name of *Hemimylacris convexa*.

Horizon.—Shales associated with the Graigola Seam. Clydach Merthyr Colliery, Clydach Valley (Swansea Vale), Glamorganshire.

ARCHIMYLACRIS (SCHIZOBLATTA) OBOVATA, sp. nov. (Pl. VII, figs. 4–6.) [Reg. Nos. 24506 & 24507.]

A markedly obovate left tegmen, the portion preserved being 23 millimetres in length, and 10 mm. in greatest breadth. The

whole of the anal and a portion of the cubital areas are missing, as also a small portion of the base. The dimensions of the perfect wing are hardly likely to have exceeded 25 millimetres in total length and 12 to 13 mm. in breadth.

The anterior margin forms a broad convex curve, almost straight as it approaches the base, and more rounded towards the narrowed and blunt apex. Beyond the apical point the inner margin is complete for half of its length, and has a well-rounded convex outline, much more pronounced than that of the outer margin. The sub-costal area is narrow, somewhat strap-shaped, but widest in the middle, and terminating acutely a little beyond the middle of the outer margin. A little of the base of the sub-costa and the proximal costal lobe are absent. The former gives off three veins, the basal one remaining single to the margin, the second giving off a simple basal branch and then forking just before reaching the margin, while the outer and final branch bifurcates near the middle of its length. Traces of a more basal vein can be seen, but whether it is a still lower branch (which is most probable) cannot be determined. All the branches of the sub-costa pass out very obliquely to the margin. The areas between the secondary veins are widest in the middle, and hollowed, the veins standing out in relief.

The radius is much the largest of the series, being separated over the greater part of its length by an unusually wide interval from the sub-costa. At a distance of 3 millimetres from the present base of the wing, it divides into two diverging branches, each of which again forks at a height of 4 mm. beyond the first bifurcation. The first branch sends off a long vein, which forks before reaching the margin, and approaches the outer vein of the sub-costa so closely as to make the interval between them about equal to that of the adjacent area. The inner division of the branch sends off, forward and outwards, a long vein which forks almost on the margin; passing forwards, it then forks at the level of the outer angle of the sub-costal area, and runs on to the outer margin. The two branches of the middle division pass out to the middle of the wing, the inner branch being concave outwards. The outer branch divides a little below the inner, and sends the resultant two veins straight to the outer margin. The inner branch first sends a simple undivided vein backwards, which reaches the margin just below the apical point; a little farther out, a simple vein is directed forward in advance of the apical point of the wing. The area of the radius is thus large, and as it passes beyond the apical point back to the inner margin, the area of the media is correspondingly reduced.

The full character of the median vein is to some extent a matter of conjecture, owing to the missing portion of the wing having carried away the basal union of the veins. A portion of the main stem is visible, from the level of the second double bifurcation of the radius, and is seen passing straight out towards the apex, until the middle of the wing is reached, where it divides

into two equal branches which curve gradually backwards to the inner border. On the inner side of the main stem, and disconnected from it, is a branch giving off a single long vein from the level of the second bifurcation of the radius, and a little farther out dividing into two equal branches. All three veins follow the same general curve of the ultimate branches of the main stem of the radius, and run out on to the inner margin. Basally, their course is such that we should expect the axis to merge into the main stem of the media, and I naturally assume that they are a part of that vein. Strong presumptive evidence of such a union is also afforded by the basal course of the next marginal veins, which appear to be separated by an interval that widens basally. The median area thus marked out is very small, and does not occupy more than a fifth of the inner wing-margin.

The cubitus is represented by six marginal veins, of which only the penultimate one to the apex is forked. Their basal direction points conclusively to a common origin; probably, however, only a little over half of the whole vein is present. There is no trace of the anal portion of the wing.

The wing is thick, coriaceous in texture, and was somewhat rounded on the upper surface. This roundness has been modified in the lower half of the wing by a little crumpling from before backwards. It is, perhaps, to the same shrinkage that we must assign the transverse wrinkles present between the veins over the radial and median areas. Unlike the purely transverse wrinkles, so evident a feature in many of the Archimylacridæ, those in the specimen here described are oblique to the veins, and not at right angles. Where they are most conspicuous, as in the marginal veins of the radius, they are seen to be very irregular in character. In some places, a close-set series start out from the side of a vein, and die out in the interspace. In other places, sets of wrinkles are interrupted by smooth interspaces, this arrangement occurring at haphazard. There are a few, but not many, cases where the wrinkles anastomose.

Affinities.—There can be no doubt as to this specimen being an Archimylacrid. Dr. Handlirsch, who has raised *Archimylacris* to the dignity of a family, Archimylacridæ, has also in the same paper[1] founded a new genus, *Schizoblatta*, and with the type-species of this genus the specimen here described is in close agreement. The points to which I attach importance are the following:—

In both, the sub-costal area extends for a short distance beyond the middle line, the veins in each case passing out obliquely to the margin. A very wide interval separates the stem of the sub-costa from that of the radius in the middle of their length, and this area is narrowed distally in each case by the approach of the marginal veins. The radius is a large and much branched vein, and separates into two main divisions, which fork at the same level and reach to the apical point of the wing—in our specimen just beyond it. The media is relatively small, while the cubitus has few branches, passing very

---

[1] 'Revision of American Palæozoic Insects' Proc. U.S. Nat. Mus. vol. xxix (1906) p. 722.

obliquely out, like those of the sub-costa, to the margin. The anal area in the type, *Schizoblatta alutacea*, is long, attaining nearly half the length of the wing. In the specimen here described the whole of this part is missing, as also a part of the cubitus. The missing portion of the inner margin extends beyond the middle of its length, and with a knowledge of how frequently the anal vein determines the line of fracture, this extended broken area becomes significant. The fact that our specimen does not wholly agree with the definition of the genus, does not invalidate the species, as the definition is founded upon one specimen of the type-species only. Dr. Handlirsch's definition is as follows:—'Front wing elliptical, about two and two-fifths times as long as broad. Costal area extending about three-fifths the length of the wing, with about nine or ten normal veins; not expanded at the base. Radius divided into two principal stems, the superior of which separates into six branches and the inferior into eight, the majority of the latter ending in the apical border. The media likewise divides into two main stems, the anterior of which forms five branches and the posterior four, all of which fuse in the apical margin. The eight branches of the gently vaulted cubitus take up the entire inner border. The anal area attains nearly half the length of the wing. Cross-veins area not to be distinguished, but instead there is a fine-grained leathery structure.' (*Loc. cit.*)

I would suggest an emendation, basing the characters of the genus upon the obliquity of the marginal veins of the sub-costa and cubitus, the presence of a wide interval between the former and the radius, and the wide area occupied by the latter. The division of the radius into two unequal branches, together with its symmetrical double bifurcation, is also, I venture to think, a feature of primary importance.

In the wide divergence of the radius and the media, the specimen here described is in agreement with Scudder's genus *Spiloblattina*; but in this case the veins do not again converge to enclose an elongate or oval area.

Horizon.—Gwernau Level of the Mynyddislwyn Vein, near Maes-y-cwmmer (Monmouthshire).

ARCHIMYLACRIS (ETOBLATTINA) HASTATA, sp. nov. (Pl. IX. figs. 1–3.)
[Reg. Nos. 24501 & 24502.]

An oblong, broadly elliptical, left tegmen, twice as long as broad: the length of the wing being 33·4 millimetres, and its breadth 16·5 mm. A portion of the base of the wing and a considerable portion of the distal and inner margins are missing; but sufficient of the wing is preserved to make these measurements approximately accurate. The wing has a strong outline, especially along the anterior margin—partly owing to the presence of a broad, shallow, concave depression, which runs almost the whole length of the subcostal and radial areas, on their outer side, and causes the anterior margin to be reflexed dorsally. Of the inner margin, only the greater part of the anal border is left, although but little of that portion which bounds the cubital area can be missing. The posterior two-thirds of the apical margin are gone, the absence of which gives an acute lobate appearance to the wing, negatived by a closer study of the inner margin. In all probability the apex was narrowly and bluntly rounded, more so than is usual in forms of this group—though not wholly unknown, as, for example, in *Archimylacris acadica* Scudder.

The most nearly related species appears to be *Archimylacris*

(Etoblattina) venusta, but the differences are sufficiently strong to merit specific rank, where, as in this group, specific identity is wholly dependent upon wing-structure. The sub-costal vein is strongly curved proximally, reaching almost to the middle of the base of the wing. Farther away it is parallel to the margin, and then passes rapidly forward and outwards in an oblique line, reaching the margin at the outer edge of the middle third of the wing. The subcostal area is thus wide at the base of the wing, and narrows outwards, ending in an acuminate peak against the tip of the distal vein. It gives off anteriorly nine, possibly ten, branches, of which the 4th, 5th, 6th, 9th, & 10th are forked, the 6th forking twice. The direction of the veins becomes more oblique to the margin from the base outwards, the last two being almost in a straight line with the sub-costa itself. The sub-costal area forms a shallow concave trough, bounded by the upturned margin anteriorly, and posteriorly by a flattened ridge which bears the bases of the radius and the median vein. A wide interval separates the sub-costa from the main stem of the radius, the interval being as wide at the base as at the level of the first forking of the latter. The first four branches of the sub-costa are slightly elevated above the general surface, the rest being flat, or, in the outer branches, sunken.

The main stem of the radius is gently arcuated, and follows a course parallel to that of the sub-costa, until the first fork is reached, when it begins to curve backwards, so that the two anterior veins are in this region separated by an unusually wide interval. The proximal third of the radius is strongly elevated, as is also the first branch up to its bifurcation. The latter arises at a point a little in advance of the level at which the first branch of the cubitus is given off, and, curving first forward and then a little backwards, passes out to the margin, giving off three forked branches of considerable length in its course. The marginal veins are parallel with one another, and with those of the sub-costa; and so the greater part of the anterior margin is marked out into eighteen to twenty strips with parallel sides. Beyond the first bifurcation the radius forks twice, once just above the middle of the wing, and again at a point apparently equidistant between the first fork and the apical margin of the wing. The precise position cannot be determined, owing to the alar structure being torn away around the critical area. All the minor veins are sunken, those of the anterior branch in the concave depression which passes outwards from the sub-costal area, those of the posterior branches passing across a flat apical area. The whole course of the radius follows a somewhat sigmoidal curve, the latter becoming flattened in the hinder portion of the radial margin.

The media arises in actual contact with the base of the radius, or is united thereto. It rapidly diverges until it becomes parallel with the inner branch of the radius, with which it keeps parallel until the first forking is reached at the end of the first third of the

wing; beyond this point the media bends backwards, and follows an almost straight course to the upper third of the inner margin, giving off four branches on its anterior side. Of these, the first forks a little above the middle of the wing, and probably the rest forked also; but the wing is torn away over the hinder half of the apical area, and this point cannot be determined.

The regularity of the minor veins over the whole of the rest of the wing makes this bifurcation a certainty. Up to the first branching, the media is raised in moderately high relief, in this respect agreeing with the basal portion of the radius. Beyond the first branching, the veins become sunken, the intervening areas being gently convex. The median area stretches along almost the entire hinder half of the apical margin, and apparently extends forward to the actual apical point. The area is much larger than in *A. venusta*, owing to the backwardly directed main stem of the media, and the short and arcuate cubitus.

The cubitus arises in close proximity to the bases of the radius and media, and gradually diverges from the latter, the divergence increasing up to the point at which the fifth branch is given off, after which it approaches the media very gradually, but still keeping a wide interval between the two. The width of this interval opposite the proximal forking of the media is especially wide. Ten branches are given off from the cubitus on its inner face, only one of which, the proximal one, is forked. This is also a little arcuated at its point of origin, and then passes out to the inner margin, bending very slightly towards the apex of the wing in its outer half, as do all the rest.

The cubital area stretches from the end of the first third of the inner margin to a little within the distal third. It is much shorter than in *A. venusta.* The first anal vein is robust, elevated in its basal half, and depressed in the distal portion. It lies in the middle of a deep broad valley, being widely separated from the base of the cubitus and the base of the succeeding anal vein. It is strongly arcuated, much more so than any of the chief veins, while it is marked off from the second anal by the swollen or tumid inner flank of the trough in which it lies. It reaches the margin about the end of the first third of the wing. Eleven other anal veins are present, which diminish in strength and also increasingly approach one another backwards. They are wider apart distally on the wing-margin than at their bases, so that the smaller inner veins appear to pass obliquely and in straight lines to the wing-margin. The inner wing-margin over the anal area is almost straight.

Viewing the wing as a whole, one is at once struck with the appearance of great muscularity, shown in two oblique ridges: an anterior one passes forwards and outwards, and bears upon its crest the main stem of the radius, being bounded in front by the base of the sub-costa, while upon its hinder face lie the bases of the median and cubital veins.

The hinder oblique ridge follows the course of the second anal, the first anal vein bounding its anterior border. Its hinder border is not defined, the convexity dying out gradually over the anal area. A median and less evident ridge carries the middle portion of the cubitus, and lies a little in advance of the other two. The whole surface is covered with a close-set series of narrow wrinkles at right angles to the veins. They are most evident over the anal area, where many of them fork between the veins, and also pass directly over the latter in places. They are least evident over the sub-costal and radial areas.

Affinities.—In the strongly arcuate outer margin and almost straight inner margin, the specimen agrees with *Anthracoblattina spectabilis* of Goldfuss. The sub-costal vein is not, however, parallel to the anterior margin, while its width at the base is more than a third that of the wing, whereas in *A. spectabilis* it is but a quarter. The radius forks much nearer the base, being subdivided practically into two main divisions. The cubitus is comparatively simple, and only the lower branch is forked, whereas in *A. spectabilis* this vein forks twice, and the succeeding three branches also fork. *A. spectabilis* is a much larger wing, having a length of 44 mm., its estimated length when complete being 54 mm., and a breadth of 22 mm., the present species being about 33 mm. in total length as now shown, but when perfect probably about 40 mm. When compared with *Archimylacris (Etoblattina) venusta* mihi, it exhibits an equally close correspondence in shape, and in the origin of the veins near the middle of the wing. Considerable differences exist, however, in the sub-costal area, that of *A. venusta* being the longest; the branches of the radius in the latter are sixteen or more in number, in the South Wales specimen there are not more than ten or eleven, and the latter reach the wing-margin very obliquely. The cubitus is a much longer vein in *A. venusta*, reaching the hinder part of the apical border, while in this specimen it runs out to the inner margin, the apical area being entirely occupied by the radial and median areas. A careful comparison with other species shows a greater divergence in structure, and I therefore regard this as a form closely allied to *A. venusta*, but with decided specific differences. The powerful muscular ridges at the base of the wing, the marked convexity of the outer margin, and its upwardly reflexed edge are characters peculiar to the species, and mark it off from all other species that I have seen.

Owing to its general spear-shaped form, I have applied to the specimen the name of *Archimylacris (Etoblattina) hastata*.

Horizon.—Gellideg Level of the Mynyddislwyn Vein, near Maes-y-cwmmer (Monmouthshire).

ARCHIMYLACRIS sp. indet. (Pl. X, fig. 3.) [Reg. No. 24503.]

A fragmentary blattoid tegmen showing the middle third of the alar area, the proximal portion being concealed under a *Cordaites* leaf, and the outer third missing.

The specimen is much too fragmentary for any attempt at specific determination. The sub-costa is represented by three branches, two of which fork low down, and therefore presumably near their points of origin. The single vein, which is the lowest, may be the upper member of a forked vein similar in character to the other two. The veins stand out in relief, the interspaces being flat. There are indications that the outer margin was bent downwards.

Judging from the course of the veins, which are very oblique, the radial area extended for a considerable distance along the outer margin. The radius is represented by three branches, the outer two forking, and the fork of the first branch being at a lower level than the second. The veins are sunken, well defined, and with flat interspaces as in the case of the radius. The direction is almost straight outwards, and there can be no doubt that the radial area reached the apical point of the wing.

The media shows five branches, the inner two converging towards a common point basally. They represent, therefore, the secondary branching of one of the lower offshoots. A somewhat wide interval separates the radius from the media, and the interspaces between the branches of the latter are narrower than those of the radius, but not so narrow as those of the sub-costa, which are the smallest. The general course of the media is outward and backward, the direction being such as would bring the branches out upon the margin behind the apical point. The median area probably included the inner half of the marginal tip of the wing.

The cubital portion of the wing is partly obscured by a much wrinkled superficial layer, the wrinkles in some cases passing straight across between the veins, and in others being thrown into crenulated lines, the convexities of which are directed basally. Some of these crenulated wrinkles pass across the interspaces from one vein to another, while others stretch across two interspaces. Over the two outer veins, two sets of straight wrinkles intersect one another, forming a small patch of irregular network. The general effect of the wrinkles is similar to that which would be produced if an easily separable epidermis or superficial layer had been pushed towards the base of the wing.

The inward inflection of the wrinkles at the veins indicates that the outer layer was attached at equidistant points along their length, while the fact that wrinkles which dip into the veins may, and occasionally do, die out in the next interspace, would seem to show that a wrinkle is a superficial corrugation, and not a lateral commissure of the veins themselves. The latter view is also negatived by the two crossed sets of wrinkles on the two outer veins. Seven cubital veins are present, the four inner being simple so far as shown, and the three outer arising from a common stem. The interspaces are convex. There is no trace of the anal area.

Scudder and others have commented upon the general association of the wings of blattoids with leaves of *Cordaites*. The base of

the wing in this case was concealed by a leaf of *Cordaites*, and others occur upon the same slab of shale. While Carboniferous blattoids may have been wholly phytophagous, it is interesting to note that all the leaves of *Cordaites* (in the present case) are impressed with shallow pits, which show faint traces of a spiral. I have, in very many previous instances, found that such pits owed their origin to attached shells of *Spirorbis pusillus*. Whether these leaves were partly submerged in water during life is an open question; but, in all cases, the plant-tissues of the pittings are depressed, and are accurate impressions of *Spirorbis*. If the Carboniferous blattoids were not wholly vegetable feeders, the occurrence of *Spirorbis pusillus* upon the *Cordaites* may supply a reason for their frequent association.

The character of the wing-fragment is typically that of an Archimylacrid. It was undoubtedly broad, and the chief veins were well defined, deep, and distinct in character one from the other.

Horizon.—Gellideg Level of the Mynyddislwyn Vein, near Maes-y-cwmmer (Monmouthshire.)

GERABLATTINA (APHTHOROBLATTINA) SULCATA, sp. nov. (Pl. VIII, figs. 1–3.) [Reg. Nos. 24504 & 24505.]

Greater part of a right tegmen. Under surface alone shown. Only a short portion of the outer margin of the wing is preserved, an estimated two-thirds of the middle, and a small portion of the anal area. Although the wing is thus fragmentary, it is fortunate that the parts preserved include the sub-costal angle and the greater part of the base with slight evidences of attachment. The inner sub-costal angle is much produced, bluntly rounded, and very broad, forming apparently a full third of the width of the base. The angle bends sharply inwards to the point of attachment, a small portion of the latter forming a narrow ill-defined neck projecting outwards from the middle of the wing-base.

The anterior margin has the appearance of having been thickened or infolded. The inner portion of the triangular sub-costal area is smooth, and separated from the venated portion by an oblique ridge arising near the base of the sub-costa, and passing obliquely forwards and outwards to the margin. The sub-costa is thin, elevated basally, and somewhat crenulated, doubtless owing to *post-mortem* changes or pressure. Its course, so far as can be judged, was parallel to the wing-margin, and in the portion exposed five branching veins are shown, all of which fork very close to the main stem. All the branches of the sub-costa pass out very obliquely, pursuing a course which would indicate a sub-costal area occupying nearly all the outer margin. The areas between the veins are flat, except in the angles of the forks, where they become convex.

The radius follows a course parallel to the stem of the sub-costa, up to the point at which it gives off the first forward branch;

beyond this point, the branch vein approaches the radius a little. The main stem of the radius follows a course parallel to the sub-costa, the parallelism being maintained by the first branch vein and the outer branch that results from its bifurcation. The portion of the radius preserved shows six branches, the first and third of which are forked. Beyond the first forking the main stem of the radius bends gently backwards, up to the middle of its length, where it begins to curve very slightly forward. The general direction is such, that in all probability the scapular area extended a little backwards behind the apical point of the wing.

The median vein arises quite close to, but is totally distinct from, the radius. The media is the least evident of all, and its course, especially in the basal half, is only determinable with difficulty. It is slightly convex outwards in its lower half, then passes straight to the apical margin. Four parallel branches are shown, one or more almost certainly bifurcating before the margin was reached. This is purely conjectural, the apical portion of the wing being broken away. The first two-thirds of the length of the media is regularly curved, the outer third passing in a straight line to the margin. The distal portion of the wing being missing, the full extent of the median area cannot be determined, but sufficient is present to show that the area did not extend outwards to the apical point, reaching the margin at about the middle distance of the lower outer half of the margin.

The cubital vein is but faintly outlined proximally, where it is almost in contact with the anal vein. It gives off eight backwardly directed and parallel branches, only the third showing bifurcation.

The anal furrow is broad and shallow at the base, passing backwards to the inner margin in a narrowing groove and by a wide and gentle curve. As a result, the anal area is unusually long, being quite a third of the length of the wing. It is somewhat convex proximally, owing to the raised, rounded inner border of the anal groove, but more remotely becomes slightly hollowed. Five subsidiary anal veins are distinguished, in addition to the primary one. Of these, the first and second fork—the first a little below the middle of its length, and the second at about two-thirds of the length. All the veins are sharp and in good relief. The wing-border all along the inner margin is curved ventrally, so that the full course of the veins to the margin cannot be followed. Not much, however, of the wing can be hidden, and probably not more than three anal veins at the most are thus obscured. The whole of the anal area is covered with multitudinous fine transverse wrinkles, anastomosing in all directions between the veins. So abundant are these branches and fusions of the wrinkles, that in some portions of the area they assume a fine reticulation.

The portion of the wing preserved has a length of 38 millimetres, and a breadth of 16 at its widest part. There can be little doubt that the perfect wing had a length of at least 45 millimetres, and

a breadth of 25. Transverse wrinkling occurs over the whole wing, the wrinkles anastomosing between the veins. Although it cannot be stated as a positive fact, the bases of the media and cubitus appear to have had a common root, or to arise in actual contact with the primary anal vein, which is much stouter than either. Both the media and the cubitus are weaker veins than any others of the series. The slight indication of the anterior margin of the wing in the basal sub-costal area shows that that margin was convex.

Affinities.—In the general characters of the veins this specimen shows an agreement with Scudder's *Gerablattina* (*Aphthoroblattina* of Handlirsch), the points in common being the weakly developed sub-costa, especially in its lower half, and the apparent union of the bases of the radius, media, and cubitus with the first anal vein. In Scudder's *G. fascigera* this union is clear, and continues along the middle line of the wing for some distance; while in the specimen here described the general structure points to a common root of no great length. In the character of the surface-wrinkles and a subordinate reticulation there is also agreement. The veins arise a little above the middle of the wing, a feature more indicative of *Archimylacris*, but scarcely confined to that family. I consider that the wing agrees most closely with the genus *Gerablattina* as defined by Scudder,[1] and with that section which Dr. Handlirsch has erected into a new genus under the name of *Aphthoroblattina*,[2] although the difference in development of the united veins constitutes a wide difference between this species and *Aphthoroblattina (Gerablattina) fascigera*, which Handlirsch takes as the type-species of his new genus. I propose for this species the name *sulcata*.

Horizon.—Gwernau Level of the Mynyddislwyn Vein, near Maes-y-cwmmer (Monmouthshire).

ORTHOMYLACRIS LANCEOLATA, sp. nov. (Pl. X, figs. 1 & 2.) [Reg. No. 24511.]

A left wing 23 millimetres long and 10 wide, elongate-lanceolate, and tapering from the outer and inner margins to the subacute apex. Both margins are slightly convex, the greatest width of the wing being at the distal end of the anal area. The apical portion of the wing has been bent inwards, producing an irregular cross-wrinkle. In its uniform tapering towards the apex, and the long bluntly-pointed appearance thus produced, the wing departs from the typical blattoid type, this departure being also emphasized by the uniform convexity of the upper surface and the character of the chief veins, which we shall presently consider.

---

[1] 'Palæozoic Cockroaches' Mem. Boston Soc. Nat. Hist. vol. iii, pt. 1 (1879) p. 97.

[2] 'Revision of American Palæozoic Insects' Proc. U.S. Nat. Mus. vol. xxix (1906) p. 719.

The sub-costal area is a little less than half of the length of the outer margin, broadly triangular, and only sends six veins to the margin. The sub-costa is thin, sunken, and gives off three forked branches which pass out in straight oblique lines. The area of the sub-costal or humeral lobe is smooth, and the outer marginal edge, up to the termination of the sub-costal area, is slightly upturned. The first two branches of the sub-costa arise very low down.

The radial vein has numerous branches, and its area occupies the greater portion of the fore part of the wing, the most distal vein reaching the margin a little short of the apical point. The main stem is thin, sunken, and divided into four principal branches, the first three of which are doubly forked, the last forking only once. The main stem has a slight sigmoidal curve, being directed forward over the first third of its length, backwards over the middle third, and forward and outwards over the last branch. All the veins are very oblique and arise low down; and thus, notwithstanding the narrowness of the wing, they are relatively long. A wide interval separates the outer branch of the sub-costa from the lower innermost branch of the radius, the interval being widest in the middle and narrowing at the wing-margin and at the base.

The media has the same general characters as the previously described veins, but does not branch until the middle of the wing is reached, and on a level with the third branching of the radius. The proximal branch curves very slightly backwards and then forward, forking twice, the hinder of the distal veins reaching the margin in the apical point. Before doing so, it forks, then reunites, the two branches enclosing a long lenticular area. Beyond the union, it forks again quite close to the margin. The second branch of the media is single throughout its length, and is a very long vein, almost half the length of the wing. A little beyond the origin of this second branch, the main stem divides into two, the inner or proximal one passing out undivided to the inner margin, which it reaches some little distance behind the apical point. The distal branch is somewhat remarkable: branching at about half the length of the proximal branch, it sends off two unequal veins. Of these, the anterior is long, and bent forwards in a strong curve, reaching the margin at the apical point, and but little removed from the tip of the long simple vein that has been already described; the inner branch is short, and passes obliquely outwards to the inner margin, leaving an unusually wide double wedge-shaped area between the two branches. As a result of this curious disposition of two branches having a common origin, a large section of the inner apical margin is destitute of veins.

The cubitus arises near, or may be united to, the base of the media. This is a point which cannot be determined, the wing-base being broken away. It at once divides into two main branches, the

outer being simple and forking once far forward, after which the branches curve gently backwards and then outwards to the margin. The inner ramus gives origin to three branches, the first and third being forked, the central simple and unbranched. The veins follow a similar course to those of the outer ramus.

The anal area has been broken away along the line of the anal furrow, the latter passing in an open curve from a little below the middle of the base of the wing outwards to the margin, which it reaches a little below the middle line.

Affinities.—The distinguishing feature of this wing is the basal branching of all the veins with the exception of the median, and the width of the area occupied by them at their origin. Usually, in the blattoid wing, the chief veins arise as nearly as possible in contact with one another; or else two or more may have a common stem. In this case they are well separated, and are spread over nearly a third of the wing-base. Another feature of unusual character is presented by the wide interspaces between the veins in the middle of the wing. These wide interspaces are well seen between the lower ends of the branches of the radius, the wide interval between the main stem of the latter vein and that of the media, and again between the latter in the middle of its length and the outer branch of the cubitus. While this open spacing is a distinctive character of Handlirsch's family Spiloblattinidæ, it is not confined to that group; and, as it is accompanied in the present instance by a markedly triangular sub-costal area, in place of a strap-shaped one, it cannot be assigned to any genus of that family. It may be noted, however, that in general form, and in wide interspaces, it agrees with the genus *Atactoblatta.* Believing that the character and the mode of branching of the veins furnish the most reliable evidences of relationship, I am of opinion that the relationships of this form must be sought for among the members of the family Mylacridæ of Scudder. Within this family Dr. Handlirsch constituted a new genus *Orthomylacris*, with the definition of which the specimen closely agrees. His definition is as follows :—

> 'Front wing two to two and a third times as long as broad, of subcordate outline. Costal area extending one-half to two-thirds the length of the wing. Radius continuing to the apical border, with a variously large number of offshoots branching forward. The superior branch either simple or forked, more rarely strongly compound. Media with few veins directed obliquely backward to the apical and inner borders. Cubitus never continuing to the apical margin, with few branches. Anal area very long, at least twice as long as high, and extending two-fifths to one-half the length of the wing, with numerous more or less compound veins. Structure leathery, more or less distinctly cross-wrinkled.' (Proc. U.S. Nat. Mus. vol. xxix, 1906, p. 768.)

Only a very few somewhat oblique cross-wrinkles can be detected upon the specimen on the inner side of the apex. Elsewhere the wing-structure is smooth or somewhat granular, the granularity being perhaps due to the impress of the material in which the wing lies embedded. The surface of the wing is flatly and regularly

convex, with the exception of the inner portion of the sub-costal margin, which is slightly upcurved. No definite trace can be detected of an anal furrow.

Owing to its marked elongate character and doubly convex margins, I apply to this form the name of *Orthomylacris lanceolata.*

Horizon.—Shales associated with the Graigola Seam, Clydach Merthyr Colliery, Clydach Valley (Swansea Vale), Glamorganshire.

LAMPROPTILIA TENUITEGMINATA, sp. nov. (Pl. X, fig. 6.) [Reg. No. 24509.]

A right hinder wing of large size and considerable tenuity. The greatest length and breadth are 29 millimetres and 7 mm. respectively. The tenuity of the wing is so great that underlying plant-remains can be seen and traced easily. A leaf of *Lepidophyllum majus* overlies and partly conceals the base.

The venation is at first sight of the same general type as that of a blattoid tegmen; the branching is more extensive, however, and the distal expansion of the wing-surface much greater. The wing appears to have been somewhat quadrangular in outline, with a sinuous inner margin, and the base is much broader than in the ordinary form of blattoid. The outer margin is probably represented by a shadowy line along the middle third of the outer wing-margin, in which case it must have been fairly straight, in this region bending in a well-rounded angle to the tip of the wing, and the latter similarly merging in the delicate sinuous inner border.

The sub-costal area is narrow, strap-shaped, and probably extended over the whole length of the outer margin. No definite trace of veins can be discerned upon it.

The radial vein divides low down near the base into two rami, the outer being the smallest. The latter first divides about the middle of the wing, sending off a simple branch which reached the broad apical margin, and curving gently backwards as it approaches the latter. Farther out, the radius sends off at equal distances two more simple branches, which follow a course parallel to the first. It is then continued as a small vein, which bends somewhat abruptly inwards at the point of forking, and approaches close to the outermost marginal vein of the inner ramus. Its backward sweep is thus greater than that of the other marginal veins of the same ramus, and its course must have brought it out upon the margin near the middle point of the tip of the wing. The inner ramus of the radius forks low down, much nearer the base than the corresponding bifurcation of the outer ramus, and the two branches into which it is divided fork again nearly at the same level near the middle of the wing. Of the four branches thus produced, the outermost remains simple to the margin, the inner branches forking on a level with the second branching

of the radius. The course of the veins is irregular, the interspaces widening and narrowing along their length. This may be due to distortion of the wing when deposited upon the mud. The marginal veins arising from the radius extend over the whole inner portion of the wing-tip, owing to their strong backward course in the final portion of their length, the direction being almost at right angles to the basal portion of the stem-vein.

The media divides almost at its point of origin, the outer branch forking a little below the middle of the wing, beyond which the veins become so attenuated that their course is but faintly outlined to the distal end of the inner margin. The inner vein forks low down, and again in the middle of the wing, the resultant four branch-veins thinning out much as do those of the outer branch. They are impressed as very faint lines, the continuity of which cannot be traced back to the inner margin.

The course of the cubitus is obscured by a reed-like plant which underlies it. It is much less distinct than the rest, only two basal portions being distinguishable.

The anal area is filled by a broad series of thread-like veins, which sweep outwards and backwards in a fan-like form to the inner margin, and occupy fully one-half of it. The innermost anal veins are quite geniculated close to their origin, so that they bend abruptly backwards. They all seem to arise from a comparatively few (four to six) stems.

The inner margin of the wing to a third of its total depth is quite filmy and veil-like, the veins crossing the area as faint shadowy lines. The outer two-thirds is more strongly impressed, while indications are present which lead to the inference that in the broad base of attachment the stem-veins were more than usually robust. No trace of transverse veins, of wrinkles, or of a reticulation is shown.

The specimen lies in a small fragile block of brown mudstone or shale, crowded with plant-remains, among which I have distinguished *Lepidophyllum majus* and *Cordaites.*

Affinities.—Hind wings of insects are so rarely found in the Coal Measures, that generic or specific determination is a matter of no small difficulty. Unless found in association with the tegmina, it may well happen that they may be referred to a different genus. Dr. Sellards,[1] who devotes more than usual attention to blattoid hind wings and also figures several, says that they did not fold longitudinally as in recent forms, and that cross-veins are not known. The inner border was full and well rounded, making the wing broad in proportion to its length. Dr. Sellards's types may best be described as broadly ovate, and much unlike the form here described. They are indeed but little removed from the tegmina in shape. Scudder, Handlirsch, and others have hardly touched this question,

---

[1] 'Structure of Fossil Cockroaches' Amer. Journ. Sci. ser. 4, vol. xviii (1904) p. 119.

and have frankly avowed that, in the present state of our knowledge, the classification of the Palæozoic cockroaches is largely artificial and a matter of convenience. That such is the case I believe few will venture to dispute.

After a considerable amount of comparison and research, I have abandoned the possibility of blattoid affinity, and find the nearest analogues to this wing in the genus *Lamproptilia* of Charles Brongniart. That author described and figured two species, *L. grand'euryi* and *L. stirrupi*,[1] which show a close agreement with the form here described. This is more closely related to *L. stirrupi* than to *L. grand'euryi*, it is more quadrangular in outline than either, and the costal area is much broader. The anal portion of the wing is of greater tenuity, and occupies fully half of the inner margin, while the latter is almost straight in its distal half. To distinguish it as a species, I assign to it the name of *Lamproptilia tenuitegminata*.

Horizon.—Level in No. 2 Rhondda Seam, 1¾ miles north-east of Resolven Station (Glamorganshire).

IV. GENERAL OBSERVATIONS.

One feature of some interest is the marked association of these blattoid wings with vegetable remains, especially the leaves of *Cordaites* and the pinnules of *Neuropteris*. In several cases the wings are interbedded with *Cordaites* leaves. The wing of *Hemimylacris obtusa* occurs in a typical underclay, and that of *Lamproptilia* in a yellowish-brown shale crowded with plant-remains. The proximity of the deposits to a land-surface seems evident. I have elsewhere alluded to the presence of sunken pits in the *Cordaites* leaves, and the possible bearing which these may have upon the use of *Spirorbis pusillus* as food by the blattoids. Scudder, Sellards, and several others have noticed the association of blattoids with fossil plants, Dr. Sellards suggesting that they were fond of moist low places with abundant vegetation, such as would be found along the banks of rivers and marshes.[2] From such situations the transference of dead insects and loose vegetation into the water would be inevitable.

Any attempt to discuss the relationship of these South Wales blattoids with those of North America or Europe could only be based upon somewhat vague conjectures. The presence of Archimylacrid and Orthomylacrid forms, no less than the presence of *Lamproptilia*, is indicative of a considerable advance in insect development in this country beyond the more primitive palæodictyopteran types; and from their abundance we may fairly

---

[1] 'Études sur le Terrain Houiller de Commentry' vol. iii (1893) pp. 467–70 & pl. xxxv (19), figs. 7–9.

[2] E. H. Sellards, 'Structure of Palæozoic Cockroaches' Amer. Journ. Sci. ser. 4, vol. xviii (1904) p. 122.

expect to find more lowly types in the Lower Series of the South Wales Coalfield at some distant date, or even traces of their presence in rocks of Older Palæozoic age. Their occurrence may also be regarded as indicating the possibility of a terrestrial fauna somewhere in the South Wales Coalfield.

In conclusion, I wish to acknowledge my indebtedness to the Director of H.M. Geological Survey, who placed the specimens in my hands for study; to Dr. Aubrey Strahan, F.R.S., for information respecting localities and the stratigraphy of the South Wales Coalfield; to Mr. J. W. Tutcher for his kindness in photographing the specimens amidst the pressure of much other work; to Mr. R. E. J. Bush, A.R.C.A., who has prepared the wing-diagrams with great skill and accuracy; and to Mr. John Pringle, of the Geological Survey.

EXPLANATION OF PLATES VII–X.

[The photographs are by Mr. J. W. Tutcher, and the line-drawings by Mr. R. E. J. Bush, A.R.C.A. All the figures are magnified 2·6 diameters; the specimens are in the Museum of Practical Geology, Jermyn Street, London, S.W.]

Plate VII.

Fig. 1. Figure of *Gerablattina arcuata* Sellards, to illustrate the terminology of the wing:—

Redtenbacher.	Heer.
I. Costa.	I. Marginal.
II. Sub-costa.	II. Mediastinal.
III. Radius.	III. Scapular.
IV. Media.	IV. Externomedian.
V. Cubitus.	V. Internomedian.
VI. Anal veins.	VI. Anal veins.

The terminology of Redtenbacher is followed in the text.

2. *Archimylacris* sp. indet. and pronotum. [Reg. No. 24508.] (See pp. 152, 153.)

Horizon.—Mynyddislwyn Vein, Gellideg Level, near Maes-y-cwmmer (Monmouthshire).

3. *Hemimylacris convexa*, sp. nov. [Reg. No. 24512.] (See p. 156.)

Horizon.—Shales associated with the Graigola Seam, Clydach Merthyr Colliery, Clydach Valley (Swansea Vale), Glamorganshire.

Figs. 4 & 5. *Archimylacris (Schizoblatta) obovata*, sp. nov. [Reg. Nos. 24506 & 24507.] (See p. 157.) Left tegmen and impression. A large portion of the inner half of the wing is missing. The impression is more complete.

Horizon.—Mynyddislwyn Vein, Gwernau Level, near Maes-y-cwmmer (Monmouthshire).

Fig. 6. Diagram showing the course of the veins in *Archimylacris (Schizoblatta) obovata*.

PLATE VIII.

Figs. 1 & 2. *Gerablattina (Aphthoroblattina) sulcata*, sp. nov. [Reg. Nos. 24505 & 24504.] (See p. 165.) Greater part of the right tegmen and impression of the same. The under surface of the wing is shown.

Horizon.—Gwernau Level of the Mynyddislwyn Vein, near Maes-y-cwmmer (Monmouthshire).

Fig. 3. Diagram showing the course of the veins in *Gerablattina (Aphthoroblattina) sulcata*.

PLATE IX.

Figs. 1 & 2. *Archimylacris (Etoblattina) hastata*, sp. nov. [Reg. Nos. 24501 & 24502.] (See p. 160.) Impression of and greater part of the left tegmen. The proximal portion and the inner half of the apex of the wing are missing.

Horizon.—Gellideg Level of the Mynyddislwyn Vein, near Maes-y-cwmmer (Monmouthshire).

Fig. 3. Diagram showing the course of the veins in *Archimylacris (Etoblattina) hastata*.

PLATE X.

Fig. 1. Left tegmen of *Orthomylacris lanceolata*, sp. nov. [Reg. No. 24511.] (See p. 167.) A portion of the base of the wing and the whole of the anal area are missing.

Horizon.—Shales of the Graigola Seam, Clydach Merthyr Colliery, Clydach Valley (Swansea Vale), Glamorganshire.

2. Diagram showing the course of the veins in *Orthomylacris lanceolata*.

3. *Archimylacris* sp. indet. [Reg. No. 24503.] (See p. 163.) A fragmentary blattoid tegmen showing the middle third of the wing-area, the rest being concealed under *Cordaites* leaves. The impressions made by the attachment of shells of *Spirorbis pusillus* can be seen upon the *Cordaites* leaf to the left.

Horizon.—Gellideg Level of the Mynyddislwyn Vein, near Maes-y-cwmmer (Monmouthshire).

4. Right tegmen of *Hemimylacris obtusa*, sp. nov. [Reg. No. 24510.] (See p. 154.)

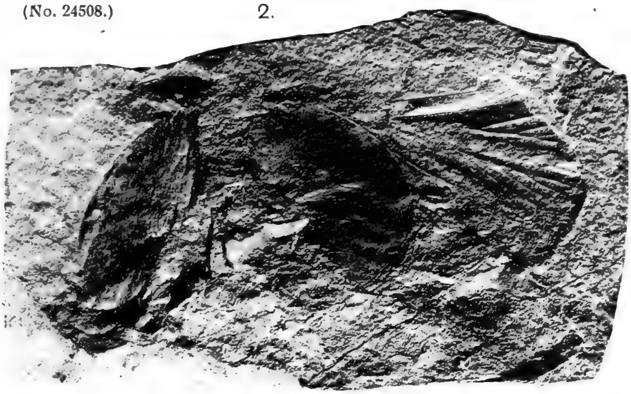
Horizon.—Four-Foot Seam of Swansea Gladys Colliery, a mile east-south-east of Penller-gaer Church (Glamorganshire).

5. Diagram showing the course of the veins in *Hemimylacris obtusa*.

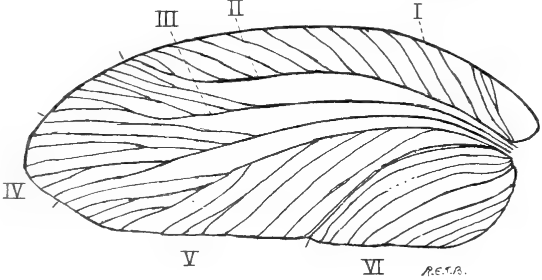
6. Right hinder wing of *Lamproptilia tenuitegminata*, sp. nov. [Reg. No. 24509.] (See p. 170.) The extreme tenuity of the wing and the almost straight inner margin are well seen in the figure.

Horizon.—Level of No. 2 Rhondda Seam, 1¾ miles north-east of Resolven Station (Glamorganshire).

(No. 24508.) 2.



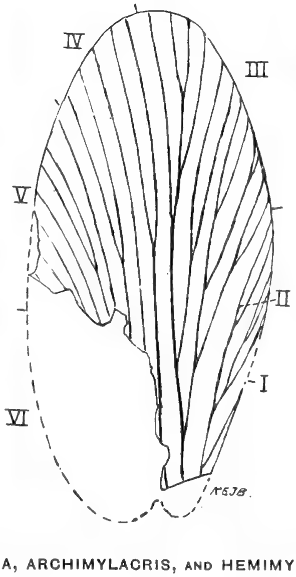
1.



(No. 24512.) 3

5.

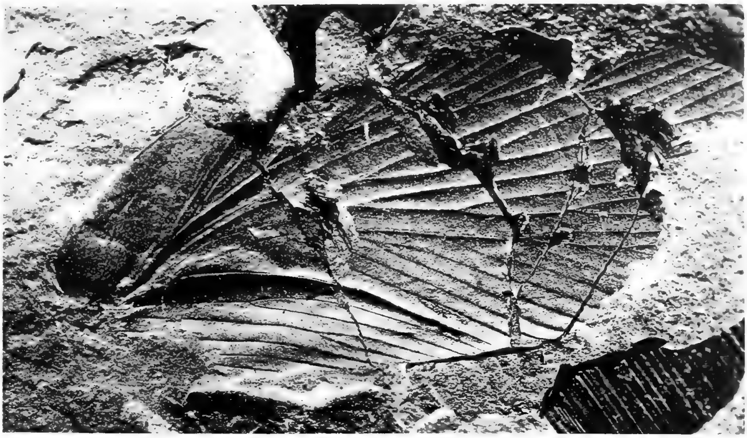
6.



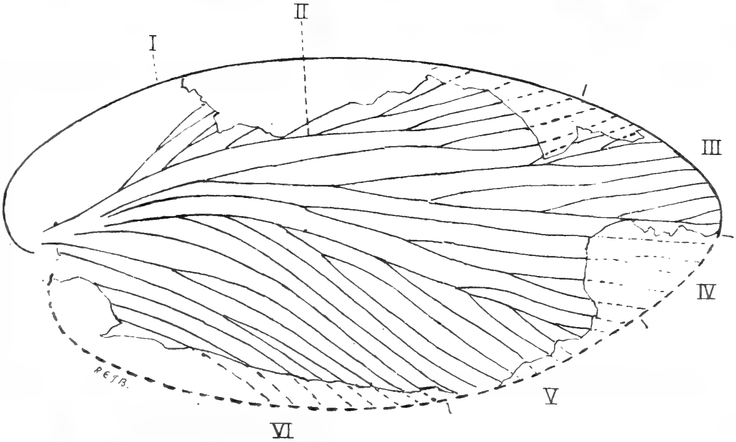
4.

J. W. Tutcher, Photogr. *Bemrose Ltd., Collo., Derby.*

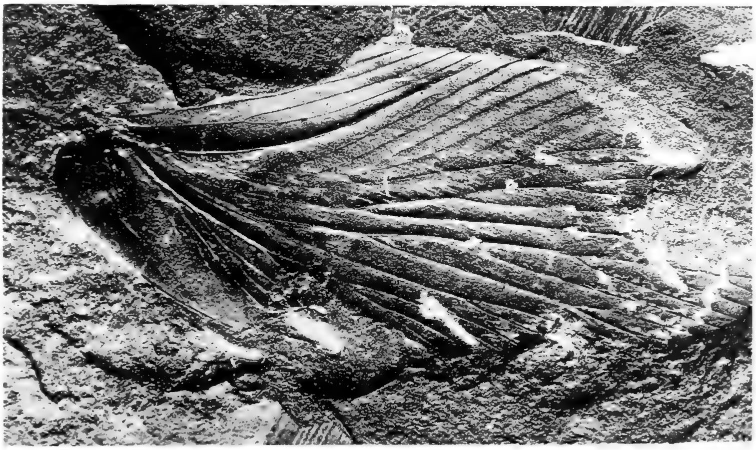
GERABLATTINA, ARCHIMYLACRIS, AND HEMIMYLACRIS.



1.



3.

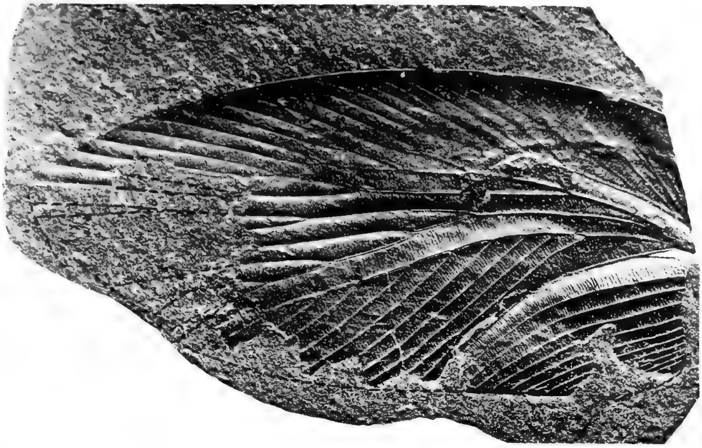


2.

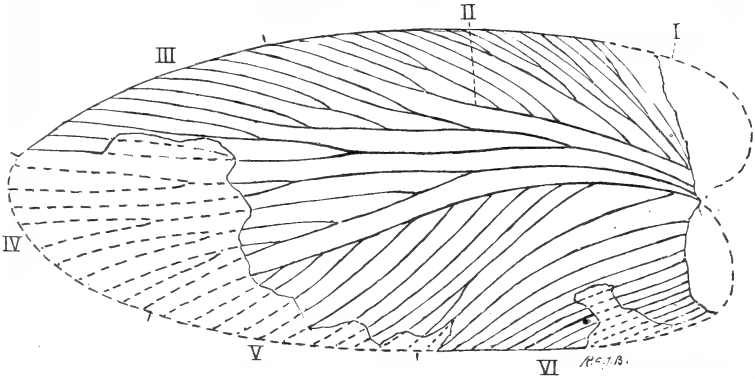
J. W. Tutcher, Photogr.

Bemrose Ltd., Collo., Derby.

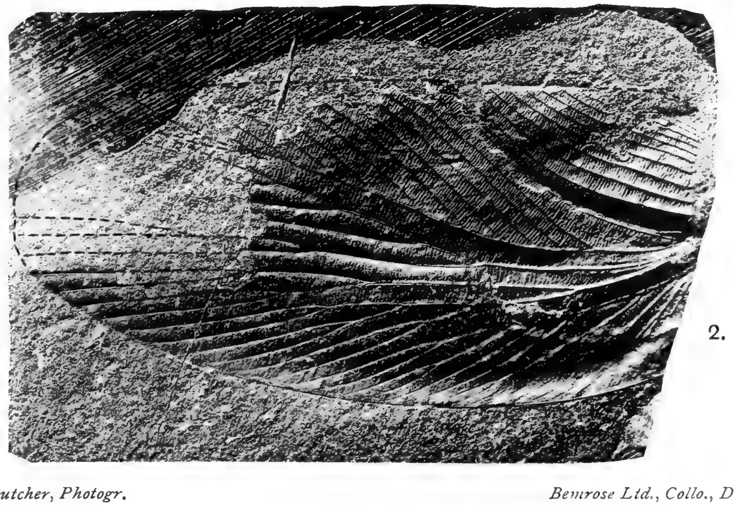
GERABLATTINA (APHTHOROBLATTINA) SULCATA.



1.



3.



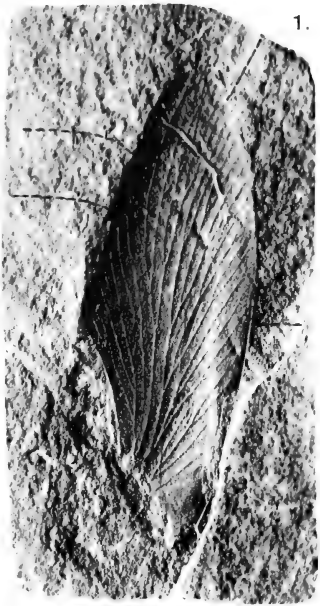
2.

J. W. Tutcher, Photogr.

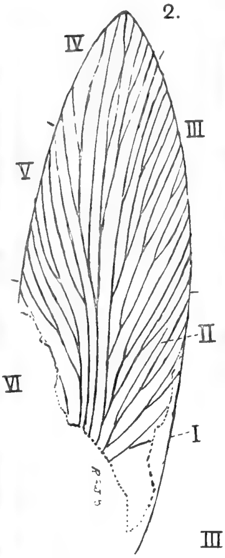
Bemrose Ltd., Collo., Derby.

ARCHIMYLACRIS (ETOBLATTINA) HASTATA.

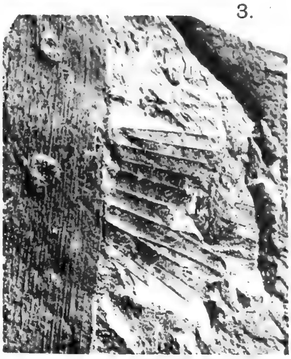
1.



2.

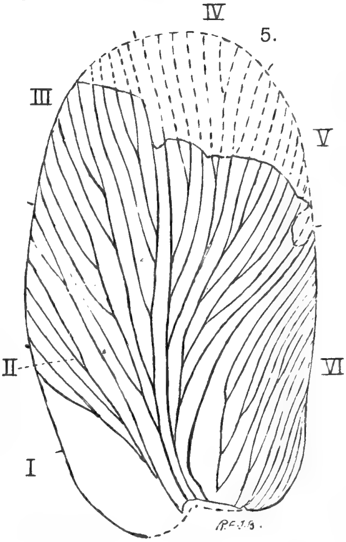


3.

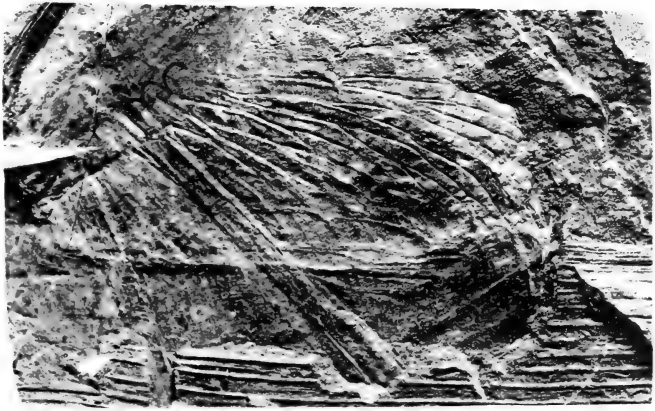


4.

5.



6.



J. W. Tutcher Photogr.

Bemrose Ltd., Collo., Derby.

ORTHOMYLACRIS, ARCHIMYLACRIS, LAMPROPTILIA, ETC.

ADMISSION AND PRIVILEGES

OF

FELLOWS OF THE GEOLOGICAL SOCIETY OF LONDON.

EVERY Candidate for admission as a Fellow must be proposed by three or more Fellows, who must sign a Certificate in his favour. The Proposer whose name stands first upon the Certificate must have a personal knowledge of the Candidate.

Fellows on election pay an Admission Fee of Six Guineas. The Annual Contribution paid by Fellows is Two Guineas, due on the 1st of January in every year, and payable in advance; but Fellows elected in November or December pay no Contribution for the current year. The Annual Contribution may, at any time, be compounded for by a payment of Thirty-Five Pounds.

The Fellows are entitled to receive gratuitously all the volumes or parts of volumes of the Quarterly Journal of the Society that may be published after their election, so long as their Annual Contributions are paid; and they may purchase any of the publications of the Society at a reduction of 25 per cent. under the selling-prices.

The Library is open daily to the Fellows between the hours of 10 and 5 (except during the fortnight commencing on the first Monday in September; see also next page), and on Meeting-Days until 8 P.M. Under certain restrictions, Fellows are allowed to borrow books from the Library.

Publications to be had of the Geological Society, Burlington House.

QUARTERLY JOURNAL. (Vols. III to LXVI, inclusive.)

Price to Fellows, 13*s.* 6*d.* each (Vols. XV, XXIII, XXX, and XXXIV to LXVI, 16*s.* 6*d.*), in cloth.

GENERAL INDEX TO THE FIRST FIFTY VOLUMES OF THE QUARTERLY JOURNAL (1845–1894). Part I (A–La). Part II (La–Z). Price 5*s.* each. To Fellows 3*s.* 9*d.* each. [Postage 3*d.*]

GEOLOGICAL LITERATURE added to the Geological Society's Library during the years ended December 31st, 1894–1909. Price 2*s.* each. To Fellows, 1*s.* 6*d.* each. [Postage 3*d.*]

THE HISTORY OF THE GEOLOGICAL SOCIETY OF LONDON, by H. B. WOODWARD, F.R.S. Price 7*s.* 6*d.* To Fellows, 6*s.* [Postage 6*d.*]

THE CENTENARY OF THE GEOLOGICAL SOCIETY OF LONDON, recorded by W. W. WATTS, F.R.S. Price 2*s.* net. [Postage 3*d.*]

LIST OF THE TYPE- AND FIGURED SPECIMENS recognized by C. D. SHERBORN in the Collection of the Geological Society, verified and arranged, with additions, by the Rev. J. F. BLAKE. 1902. Price 3*s.* 6*d.* (bound in cloth); 3*s.* 0*d.* (in paper wrappers). To Fellows, 2*s.* 6*d.* and 2*s.* 0*d.* [Postage 3*d.*]

HUTTON'S 'THEORY OF THE EARTH,' Vol. III., edited by Sir ARCHIBALD GEIKIE, D.C.L., F.R.S. Price 3*s.* 6*d.* To Fellows, 2*s.* [Postage 4*d.*]

THE GEOLOGY OF NEW ZEALAND. Translated by Dr. C. F. FISCHER from the works of MM. HOCHSTETTER & PETERMANN. With an Atlas of Six Maps. Fellows may purchase one Copy of this Book at 2*s.* Additional Copies will be charged 4*s.* [Postage 5*d.*]

CONTENTS.

PAPERS READ.

[No. 266 of the Quarterly Journal will be published next May.]

⁂ The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

The Library and Museum at the Apartments of the Society are open every Weekday from Ten o'clock until Five, except during the fortnight commencing on the first Monday in September, when the Library in closed for the purpose of cleaning; the Library is also closed on Saturdays at One P.M. during the months of August and September. It is open until Eight P.M. on the Days of Meeting for the loan of books, and from Eight P.M. until the close of each Meeting for conversational purposes only.

Vol. LXVII. Part 2. MAY 31st, 1911. **No. 266.**

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY.

EDITED BY

THE ASSISTANT-SECRETARY.

[With Twelve Plates, illustrating Papers by Mr. H. H. Thomas, Miss G. R. Watney & Miss E. G. Welch, Mr. A. Wade, and Mr. G. E. Dibley.]

LONDON:
LONGMANS, GREEN, AND CO.
PARIS:—CHARLES KLINCKSIECK, 11 RUE DE LILLE.
SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.
Price Five Shillings.

LIST OF THE OFFICERS AND COUNCIL OF THE GEOLOGICAL SOCIETY OF LONDON.

Elected February 17th, 1911.

President.

Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.

Vice-Presidents.

Charles William Andrews, B.A., D.Sc., F.R.S.
Alfred Harker, M.A., F.R.S.
John Edward Marr, Sc.D., F.R.S.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.

Secretaries.

Prof. Edmund Johnston Garwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S.

Foreign Secretary.

Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.

Treasurer.

Aubrey Strahan, Sc.D., F.R.S.

COUNCIL.

Henry A. Allen.
Tempest Anderson, M.D., D.Sc.
Charles William Andrews, B.A., D.Sc., F.R.S.
Henry Howe Arnold-Bemrose, J.P., Sc.D.
George Barrow.
Prof. Thomas George Bonney, Sc.D., LL.D., F.R.S.
Prof. William S. Boulton, B.Sc.
James Vincent Elsden, D.Sc.
John Smith Flett, M.A., D.Sc.
Prof. Edmund Johnston Garwood, M.A.
Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.
Alfred Harker, M.A., F.R.S.
Robert Stansfield Herries, M.A.
Bedford McNeill, Assoc.R.S.M.
John Edward Marr, Sc.D., F.R.S.
George Thurland Prior, M.A., D.Sc.
Prof. Sidney Hugh Reynolds, M.A.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.
Aubrey Strahan, Sc.D., F.R.S.
Herbert Henry Thomas, M.A., B.Sc.
Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.
Rev. Henry Hoyte Winwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

Assistant-Secretary, Clerk, Librarian, and Curator.

L. L. Belinfante, M.Sc.

Assistants in Office, Library, and Museum.

W. Rupert Jones. Clyde H. Black.
Arthur Greig.

STANDING PUBLICATION COMMITTEE.

Prof. W. W. Watts, *President*.

Prof. E. J. Garwood, } *Secretaries.*
Dr. A. Smith Woodward, }

Mr. H. A. Allen.
Dr. C. W. Andrews.
Dr. J. V. Elsden.
Dr. J. S. Flett.
Mr. A. Harker.
Mr. R. S. Herries.
Dr. J. E. Marr.
Dr. G. T. Prior.
Prof. S. H. Reynolds.
Prof. W. J. Sollas.
Dr. A. Strahan.
Mr. H. H. Thomas.

EVENING MEETING OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

SESSION 1910–1911.

1911.

Wednesday, June 14*

[*Business will commence at Eight o'Clock precisely.*]

The asterisk denotes that the Council will meet on that date.

5. *The* SKOMER VOLCANIC SERIES (PEMBROKESHIRE).[1] By HERBERT HENRY THOMAS, M.A., B.Sc., F.G.S. (Read January 25th, 1911.)

[PLATE XI—GEOLOGICAL MAP.]

CONTENTS.

I. INTRODUCTION.

THE region in which this volcanic series is developed occupies an extensive area in the extreme west of Pembrokeshire on the southern side of St. Bride's Bay, and includes the islands of Midland, Skomer, Grassholm, and the Smalls.

Skomer is by far the largest of the islands, and is situated about two-thirds of a mile from that part of the mainland which is known as Wooltack. It has a length, from east to west, of about 2 miles, a breadth of a little over a mile, and an area of 722 acres. Between it and the mainland lies the small island of Midland, with an area of 21½ acres, which is separated from Skomer by the Little Sound, only about 100 yards in width, and from the mainland by the broader stretch of water known as Jack Sound.

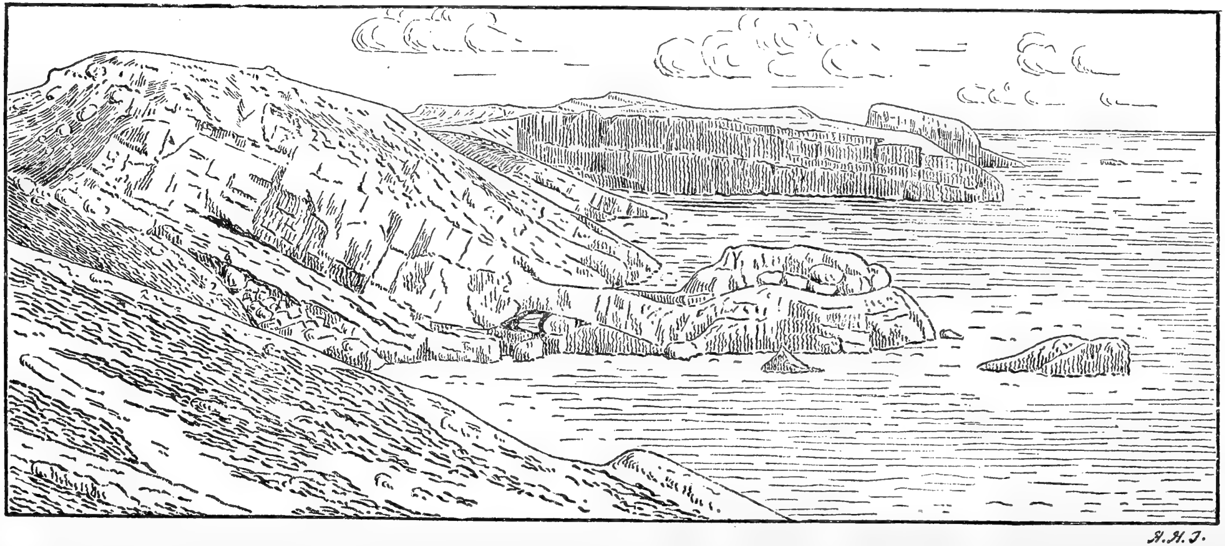
Grassholm Island lies 8 miles to the west of Skomer and covers an area slightly less than that of Midland, while the Smalls, which occupy only three-quarters of an acre, lie 8 miles to the west of Grassholm.

Skomer Island is a detached portion of that plateau which is so well marked in the west of Pembrokeshire: it rises more or less

---

[1] Communicated by permission of the Director of H.M. Geological Survey.

Fig. 1.—*The south-western coast of Skomer Island, seen from Skomer Head: the rocks are dipping away from the observer.*



[The foreground is a dip-slope of skomerite which passes beneath the rhyolite of Tom's House and the Basin occupying the first and second promontories. The third promontory is composed of sedimentary rocks, as also is the end of the Wick. The vertical fault-face on the south side of the Wick is of basalt, and above may be seen the scarps of a red rhyolite and basalts, while a fault-scarp continuous with the line of the Wick stretches away to the eastward. The island in the distance is the Mewstone, and consists of a mass of soda-felsite.]

abruptly to an elevation of 200 feet; but, on account of the smaller size of Grassholm, the highest levels attained by this island fall some way short of the usual plateau-horizon, while the Smalls rise only a few feet above the level of high-water at spring-tides. All these islands, and that portion of the mainland which will here be described, present a somewhat irregular coast-line, the form of which may be easily explained after a study of the geological features. The major indentations are due to differential erosion controlled by variations in rock-texture and rock-composition; while most of the narrow inlets owe their formation to the erosive action of the sea along planes of weakness determined by steeply-dipping faults.

The cliffs, as a rule, are fairly steep and give excellent sections, especially on the northern, western, and eastern sides; but, on account of the dip of the rocks being at a moderate angle to the south or south-east, the southern sides of the islands are generally less precipitous and the cliffs tail off to sea-level in a succession of dip-slopes.

Skomer Island, in addition to the planing which it has suffered in common with the mainland, has had all the remaining depressions filled with loamy sands and gravels of glacial origin, leaving the solid outcrops projecting, as isolated knolls and ridges, from almost flat surroundings.

There is little doubt that the Volcanic Series has a more or less continuous westerly extension from the mainland to some way beyond the Smalls, for a distinct ridge is indicated on the Admiralty chart. Moreover, between Grassholm Island and the Smalls are numerous rocks, known as the Hats and Barrels, which are just awash at the low water of spring-tides.

This ridge, however, although it joins all the exposures of the Volcanic Series, is not parallel to the strike of the rocks, but probably owes its direction to a system of north-and-south faults, with westerly downthrows, similar to those observable on the mainland between Musclewick and Wooltack, which repeatedly displace the outcrop of the volcanic series northwards.

It can be proved that the volcanic rocks continue to a point some 20 miles to the west of Wooltack, and, on the mainland, they can be followed eastwards and south-eastwards for 6 miles to the neighbourhood of St. Ishmael's,[1] on Milford Haven.

Skomer, Midland, and Grassholm Islands were surveyed during the year 1908, and the Wooltack promontory in the following year, when the Smalls rocks were also visited.

II. Previous Literature.

The previous accounts of the Skomer Volcanic Series are limited to the writings of quite a few authors, and little of importance was published until Messrs. Howard & Small undertook a study of the geology of the island.

---

[1] T. C. Cantrill, in 'Summary of Progress for 1909' Mem. Geol. Surv. 1910, p. 21.

The following is a list of the chief works and papers which refer to, or deal solely with, the geology of Skomer Island and the Skomer Volcanic Series, arranged in chronological order:—

1823 [1826]. H. T. De la Beche. Trans. Geol. Soc. ser. 2, vol. ii, pt. 1, p. 8.

He mentions the 'trap' of Marloes and Skomer Island, and states that the mass consists principally of 'greenstone,' but contains rocks intermediate in character between 'cornean' and 'greenstone.' On the map published with his paper Skomer Island is coloured as consisting entirely of igneous rocks, but it is evident that he had noted the sediments which are exposed on the eastern side of North Haven.

1839. R. I. Murchison. 'Silurian System' pp. 404 & 405.

Refers to the stratified and unstratified 'trap-rocks' of Skomer. He makes the statement that felspar-breccias and conglomerates alternate conformably in thick parallel masses with regularly stratified purple-green and yellow sandstone and schist of the 'Upper Cambrian System.' Presumably he suggested a Cambrian age for these rocks, on account of their colour and their unfossiliferous nature.

He evidently thought that some of the Skomer rocks were intrusive, for he remarked that 'the intrusive trap cuts in vertical dykes through the bedded trap and sandstone.' This statement, however, cannot be substantiated by reference to any known section, and it is presumed that he was misled by the isolated exposures occurring in the interior of Skomer.

Pl. xxxv, fig. 10 gives a somewhat misleading section, and on the map the Upper Llandovery rocks to the south of Wooltack are lettered as Llandeilo Flags.

1845 to 1857. Publication of the Geological Survey Map, Old Series, 1 inch to 1 mile, Sheet 40. Surveyed by H. T. De la Beche, A. C. Ramsay, W. T. Aveline, and J. Rees, Jun. Revised in 1857, with the addition of Silurian and igneous lines by W. T. Aveline.

In this map all the igneous rocks are coloured as 'intrusive greenstone,' and the sediments of the Skomer Series are lettered as 'Llandeilo Flags.'

1867. R. I. Murchison, 'Siluria' 4th ed. pp. 53, 143.

He here, presumably relying on the work of the geological surveyors, assigned the igneous rocks to the Llandeilo or Bala Series, but the evidence for this correlation is not given.

1881. F. Rutley. Appendix to a paper on the Microscopic Structure of Devitrified Rocks from Beddgelert and Snowdon. Q. J. G. S. vol. xxxvii, p. 409.

He gave the first petrological description of any rocks of the Skomer Series, but unfortunately without any locality other than 'Skomer Island.' The four rocks described by him, which had been collected some time previously by Sir Andrew Ramsay, were named (1) devitrified banded obsidian, (2) devitrified banded and spherulitic obsidian, (3) basalt or andesite, and (4) quartz-oligoclase trachyte (?).

These slides are preserved in the Geological Survey Collections, and correspondingly numbered.

1885. F. Rutley. 'Felsitic Lavas of England & Wales' Mem. Geol. Surv. pp. 18–20.

He here described in greater detail the spherulitic and banded obsidians already mentioned, his remarks being evidently based on the specimens collected by Ramsay and preserved in the Jermyn Street Museum.

These rocks can now be referred with certainty to the spherulitic and banded rhyolite of Tom's House on the west side of Skomer Island (see p. 187).

1888. J. J. H. Teall. 'British Petrography' pp. 224, 284, & 336.

He described the less acid rocks of Skomer as a 'magnificent series of basic lava-flows,' and referred them mainly to basalts and porphyrites. He noted that they possess characters of their own, which rendered it difficult to class them with rocks already described by other authors.

1893. F. T. Howard & E. W. Small. Rep. Brit. Assoc. (Nottingham) p. 766.

'On some Igneous Rocks of South Pembrokeshire, &c.'

In this is given a preliminary account of the geology of Skomer Island.

1896. F. T. HOWARD & E. W. SMALL. Rep. Brit. Assoc. (Liverpool) p. 797. 'Geology of Skomer Island.'

The authors give a brief general account of the geology of Skomer Island, identifying the spherulitic felsite described by Rutley as that exposed at Tom's House. They divide the rocks into basalts and porphyrites and felsites, and give a brief description of the microscopic characters of those types from a few localities. They detected no fossils in the associated sedimentary rocks, but regard the volcanic rocks as belonging to the Bala or Llandovery Series.

1896. F. T. HOWARD & E. W. SMALL. 'Geological Notes on Skomer Island' Trans. Cardiff Nat. Soc. vol. xxviii, pp. 55–60 & pl. i.

In this paper the authors published a sketch-map, on a scale of 2 inches to 1 mile, of Skomer, Midland, and part of the mainland, and six drawings of rock-sections. The rocks illustrated are 'basalt' and 'felsite,' the former including rocks which would now be classed as keratophyres. With the exception of the illustrations, this paper contains substantially the same material as the British Association Report for the same year.

1897. F. T. HOWARD & E. W. SMALL. 'Further Notes on Skomer Island' Trans. Cardiff Nat. Soc. vol. xxix, pp. 62–63.

A short description, with plate, of the section exposed in Pigstone Bay (Skomer), with additional remarks on other parts of the island. The authors regard the volcanic rocks of Skomer and the mainland as contemporaneous in character, and as being of Bala age.

1897. Sir ARCHIBALD GEIKIE. 'Ancient Volcanoes of Great Britain' vol. i, p. 207.

Refers to the interesting alternation of basic and acid eruptives, and summarizes the chief points presented by earlier authors.

1899. E. W. SMALL. 'A Note on some Skomer Photographs' Trans. Cardiff Nat. Soc. vol. xxx, p. 60.

Gives a full-page illustration of the Wick and another of the Mewstone and Channel, with a brief description.

Undated. E. W. SMALL. 'On the Geology of Skomer & some other Islands of South Pembrokeshire.' A privately printed [1899] but unpublished paper, 4to, 18 pp., with map of Skomer on the scale of 3 inches to 1 mile, and five other photographic plates of views and micrographs. Two copies of this work were completed in 1909 by Mr. Small, who, at my suggestion, deposited one in the Library of the Geological Society, and kindly presented the other to the Library of the Geological Survey.

This work contains a summary of all the important papers mentioned above, but presents much fresh material of the nature of measured sections and petrographical detail.

The rocks are described as basalts, andesites, and felsites.

III. THE STRATIGRAPHICAL RELATIONS AND AGE OF THE SERIES.

That the Skomer Volcanic Series consists almost entirely of true lava-flows has been proved by the work of previous observers, and is clearly demonstrated by the individual thinness of the successive layers; the vesicular and slaggy upper and lower surfaces; the frequent occurrence of well-defined fluxion-structures; and the interlamination of the volcanic rocks with thick masses of sediment largely made up of the igneous rocks which underlie them.

So far as can be judged, the igneous rocks and sediments have perfectly conformable relations, although in some instances the former show some signs of contemporaneous erosion. It follows, therefore, that these sediments must be regarded as forming part

of the Skomer Volcanic Series; but, owing to their unfossiliferous nature, due perhaps to the conditions of deposition, they afford no positive evidence as to the age of the Series as a whole, and for this we must turn to a consideration of the relations of the Series to the fossiliferous rocks which bound it on the south and on the north.

On Skomer and the other islands neither the upper nor the lower limit of the volcanic rocks is reached; but on the mainland at Wooltack a very complete section reveals the junction of the Upper Llandovery rocks with the upper portion of the Volcanic Series, while at Musclewick lower horizons of that Series are seen in juxtaposition to Llandeilo Flags (p. 182).

We will first consider the relations of the Series to the Upper Llandovery. The clearest section is that displayed on the northern side of Renney Slip and in the bay to the north. The rocks dip steadily southwards, and as we proceed northwards the cliffs present a downward succession described in the following paragraphs.

The steep dip-slope, which forms the northern side of Renney Slip, consists of fairly thick-bedded fossiliferous quartzites and conglomerates,[1] overlain here and there by fossiliferous shales which have yielded many characteristic Upper Llandovery fossils,[2] such as *Cœlospira hemisphærica* (J. de C. Sow.), *Rhynchonella decemplicata* (J. de C. Sow.), *Stropheodonta (Brachyprion) compressa* (J. de C. Sow.), *Encrinurus punctatus* (Brünn), and *Phacops* cf. *stokesi* (M.-Edw.).

Below these quartzites comes a basic lava-flow with thin tuffs, which occupies the small promontory of the Limpet Rocks. As this volcanic horizon has been noted at other localities, it has proved the most useful datum upon which to base the correlation of this with other sections. Below the lava-flow comes a series of grits, some of which are calcareous and have yielded an Upper Llandovery fauna, a large number of fossils having been collected from decalcified grits at the base of the cliff in the southern corner of Anvil Bay. It is thus proved that this lava is of Upper Llandovery age.

These beds pass down into a thick series of unfossiliferous grits and dark shales, which ultimately comes to rest on a mass of dolerite. The dolerite occupies Anvil Point, and is regarded as forming part of the Skomer Volcanic Series.

The complete sequence is represented by the vertical section given below (fig. 2, No. I, p. 181). On the evidence of this section, it would appear that the Skomer Volcanic Series forms the lowest part of, or is older than, the Upper Llandovery.

Another section (fig. 2, No. II) on the north, separated from the first by east-and-west disturbances of considerable magnitude, is to be seen in the two bays known as Jeffry's Haven and Mouse's Haven.

---

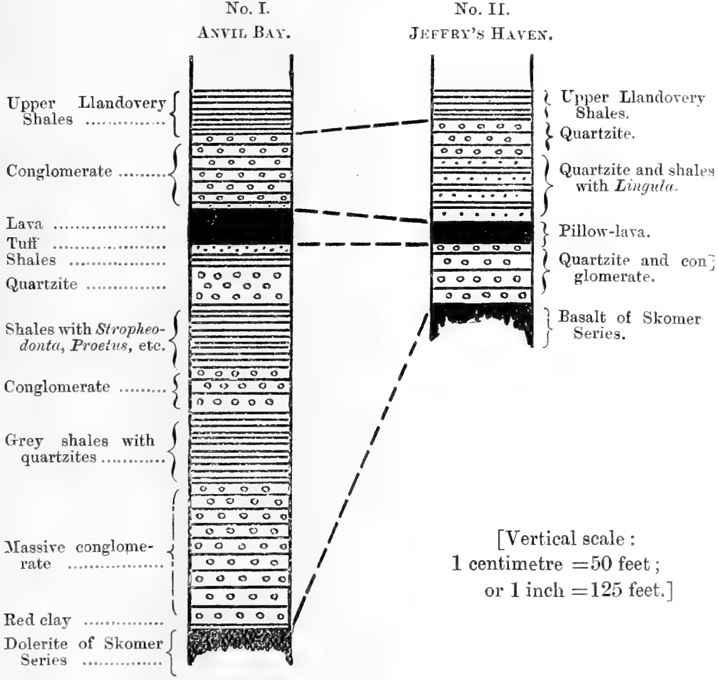
[1] These quartzites and conglomerates constitute the 'Tentaculite Grit' of earlier writers.

[2] Identified by Prof. O. T. Jones, and preserved in the Geological Survey collections.

Jeffry's Haven shows Upper Llandovery shales resting upon quartzites and shales, and followed downwards by the basic lava which here takes on a good pillow-structure. Below the lava are more quartzites about 50 feet in thickness, which rest directly upon typical sediments and volcanic rocks of the Skomer Series. Although there are some signs of movement between the Skomer Series and the overlying Llandovery rocks, it seems unlikely that any beds have been removed from the sequence.

Taking the Llandovery volcanic horizon as a datum (see fig. 2), and comparing the thickness of Llandovery sediments represented below it in the two sections, we at once notice a great disparity; for, whereas there are at least 250 feet of beds between it and the Skomer Series in the Renney Slip and Anvil Bay section, there are, at the most, only 50 feet of beds in the Jeffry's and Mouse's Haven section. This would point to an overlap within the Upper Llandovery and an overstep of the Upper Llandovery on to the Skomer Series. Therefore, despite apparent concordance in dip and strike, I am inclined to the conclusion that the Upper Llandovery rests unconformably upon the Skomer Series, and that the volcanic rocks are thus of pre-Upper Llandovery age.

Fig. 2.



[Vertical scale:
1 centimetre = 50 feet;
or 1 inch = 125 feet.]

Unfortunately, this is the only direct evidence as to the age of the series that it is possible to bring forward; but much important information which bears indirectly upon this subject can be gathered from other districts in the west of Pembrokeshire.

At Musclewick, a little over a mile to the east of the map, near the village of Marloes, the lower limit of the Skomer Series is reached. Concerning this, Mr. T. C. Cantrill has kindly furnished the following account:—

> 'The lower limit of the Skomer Series is revealed between St. Ishmaels and Marloes. A rhyolite, which here forms the lowest exposed member of the Volcanic Series, is everywhere bordered on its northern or lower margin by an outcrop of Llandeilo Flags from which it dips away without obvious discordance. At first sight, therefore, it would appear as if the igneous series was newer than, and immediately succeeded, the Llandeilo Flags, and might therefore be referable either to that formation or to some part of the Bala or Lower Llandovery Series. Further examination, however, of the section exposed in Musclewick Bay proves that there the junction of the volcanic rocks with the Llandeilo is a faulted one; but, unfortunately, the fault is vertical, and the direction of movement remains uncertain. This section, therefore, still renders it possible for the igneous rocks to be newer than the Llandeilo Flags, against which they are faulted; but general considerations make it probable that the whole length of junction is a fault, along which the volcanic rocks as older beds have been thrust from the south on to the newer Llandeilo Flags.'

It appears, therefore, that while pre-Upper Llandovery in age they may be even pre-Llandeilo. This suggestion is borne out by a consideration of the sequence of Lower Palæozoic rocks exhibited in the neighbourhood of Haverfordwest, about 10 miles away. In that district there is practically an unbroken succession from the Upper Llandovery to well down in the Arenig Series, and in this sequence there is no indication of any marked period of vulcanicity, neither is there any stratigraphical break of sufficient magnitude to mark the eruption of some 3000 feet of volcanic rock in an area so close at hand and along the same line of strike. Of course, we are aware that both the beginning and the close of the *Didymograptus-murchisoni* Zone and the upper limit of the Llandeilo Series were horizons of volcanic activity in other districts; but in South Wales, south of the pre-Cambrian ridges of St. David's and Hayscastle, these horizons are marked only by thin ashes, which show no tendency to greater development in a westerly direction.

In the *Didymograptus-extensus* Zone, however, we meet with evidence of prolonged volcanic activity, as indicated by the great thickness of acid and intermediate lavas at Trefgarn,[1] north of Haverfordwest. The Trefgarn Volcanic Series, in the composition of its members, presents many characters in common with those of the Skomer Series, and the rocks evidently belong to the same petrological province, although not showing the variety of the Skomer Series.

---

[1] The age of these rocks has lately been established by the discovery of an Arenig graptolite-fauna in shales associated with the volcanic rocks in Trefgarn gorge. See 'Geology of the Country around Haverfordwest' Mem. Geol. Surv. (in the press).

Below the *Extensus* Zone, from the *Nesuretus* Beds of Hicks to the base of the Cambrian, there seems no place for a volcanic series of such magnitude; nor in the pre-Cambrian rocks of St. David's or of the Hayscastle[1] district are there any rocks that have much in common with those of the Skomer Series. Such as the evidence is, therefore, it seems to point to the series being of Arenig age and on the same horizon as the rocks of Trefgarn, and of Llangynog in Carmarthenshire,[2] that is to say, probably rather low down in the *Didymograptus-extensus* Zone.

IV. The Volcanic Rocks.

The igneous rocks of the Skomer Series as developed on Skomer Island, where the greatest thickness can be studied, consist almost entirely of groups of lava-flows of varying composition, unaccompanied by dyke-rocks of any description, and penetrated only by a few basic sills.

The subaërial character of the flows seems to be proved by the frequent occurrence of beds of red clay; by the red staining of many of the scoriaceous and highly vesicular surfaces; by the conglomeratic layers at the top of certain flows; and also by the character of the associated coarse sediments.

The thickness of rock exposed on Skomer exceeds 2900 feet, and even then neither the base nor the summit of the Series is reached: all this is built up of flows which seldom attain 10 feet in thickness, and are often thinner, except in the case of the more acid rocks.[3]

That the eruptions were of the fissure-type is suggested by the general absence of pyroclastic rocks, and by the great lateral extent of individual flows compared with their thickness. The vents lay probably to the west of Skomer, as is indicated by the thinning of the series and the more rapid alternation of types in an easterly direction. Most of the rhyolites and the dolerites seem to thin out eastwards, and whole groups represented on Skomer are missing on the mainland.

(a) The various Rock-Types.

The rock-types previously said to be represented in the Skomer Series are the basalts, andesites, porphyrites, felsites, and devitrified obsidians of Rutley, Teall, and Howard & Small.

Through the kindness of Messrs. Howard & Small I have been enabled to work at the large number of rock-slices which they had had made, and in addition have studied some 250 slices of rocks collected during the recent survey. It has thus proved possible to separate the rocks according to eight distinct types, for two of

---

[1] These rocks have lately been mapped by Prof. O. T. Jones and myself.

[2] T. C. Cantrill & H. H. Thomas, Q. J. G. S. vol. lxii (1906) p. 223.

[3] J. J. H. Teall, 'British Petrography' 1888, p. 224.

which it has been thought advisable to take the names skomerite and marloesite.

The main rock-types which have been mapped are the following:—soda-rhyolite and felsite, albite-trachyte, keratophyre, skomerite, marloesite, mugearite, olivine-basalt, and olivine-dolerite.

The acid rocks are easily separated in the field from those of more basic character; but further subdivision on the ground is difficult, on account of the fine texture of the lavas. Generally speaking, however, the olivine-basalts can be detected by their darker colour, finely crystalline character, and by having a purple tinge imparted to them by the augite.

It has not been possible to separate in the field the trachytes, keratophyres, skomerites, and marloesites one from the other, except in a few instances. As a whole, however, these rocks may be separated from the rhyolites on the one hand, and the mugearites and basalts on the other, by their greenish or greenish-grey colour and more vesicular nature.

(*b*) Their Geographical Distribution.

The geographical distribution of the Skomer Volcanic Series as a whole has, for the most part, been clearly indicated by previous writers.

The rocks near St. Ishmael's, however, were regarded as intrusive, and were shown on the old edition of the Geological Survey Map (O.S. Sheet 40) as crossing the strike of the sedimentary rocks with which they are associated. Mr. Cantrill[1] has clearly demonstrated their true character, and described their extent.

In detail, the members of the Skomer Series have a simple distribution. The islands of the Smalls and Grassholm are too remote to allow of a detailed correlation with Skomer and the mainland; but Skomer, Midland, and the mainland are directly comparable.

A most useful datum, in addition to that of the sedimentary group, is furnished by a band of red felsitic rock which occurs just south of the Wick on Skomer Island, and lies 250 feet above the sediments. It may be detected on the Neck and on Midland Island, where, on account of its superior hardness and splintery fracture, it makes conspicuous crags.

The subdivisions as developed on Skomer may be found to a limited degree on the mainland; but the rocks are evidently thinning in an easterly direction, and some of the minor divisions have disappeared. The rhyolite of Musclewick (east of the map) might well be on the horizon of that of the North Cliff of Skomer. It is presumably succeeded by the mugearitic group of Wooltack, which may represent that of the centre of Skomer: the lower basalts of Skomer being unrepresented on the mainland. The keratophyres, etc., below the main mass of sediments, and the basalts above the sediments, are present in both areas. Minor differences between

---

[1] 'Summary of Progress for 1909' Mem. Geol. Surv. 1910, p. 21.

the various districts would be expected, but in general the agreement is fairly close.

With regard to the mode of occurrence and distribution of the rock-types, I have little to add to what has been admirably put forward by Messrs. Howard & Small and to what may be gathered from a study of the appended map (Pl. XI).

(*c*) The Rarity of Tuffs and Agglomerates.

As is far from unusual in a volcanic series of this nature, pyroclastic rocks are of exceptional occurrence,[1] and, when they do occur, they are chiefly associated with the more siliceous rocks. On Skomer Island a thin series of rhyolitic tuffs, well bedded and reaching 8 feet in thickness, underlies the trachyte of Pigstone Bay, but is not present on the eastern side of the island.

A zone of rhyolitic breccia in the north-east of Skomer, called by Mr. Small (1899–1909) the Waybench Breccias, is presumably on the horizon of the rhyolite of the Table (*op. cit.* p. 10) and represents the breaking up of the flows in an easterly direction. Similar brecciation is noticed in the pink felsitic rock on the Neck and Midland Island (below). There is almost complete absence of any tuffs of intermediate character; but traces may be observed, on the surfaces of many flows, in the form of highly siliceous flinty patches of clastic material occupying small hollows in the lava-surfaces. Such patches may be studied in Welsh Way and on the Neck. Sections indicate that the ash has undergone much silicification. On the mainland a thin series of tuffs may be seen in the cliffs on the north side of Cable Bay, below the quartzites.

V. THE PETROGRAPHY OF THE VOLCANIC ROCKS.

(*a*) The Soda-Rhyolites and Felsites.

The rhyolitic rocks of Skomer and the mainland are, for the most part, pale as regards colour, varying from white to cream; but occasionally they have a distinct violet tinge, such as is observable in the flows which form the half-tide rocks between the Garland Stone and the North Cliff of Skomer. The rocks of the North Cliff are often beautifully banded, but seldom spherulitic; those of Manies Island are both spherulitic and vesicular.

The flows of Tom's House and the Basin are spherulitic and banded rhyolites, of which the altered spherulites attain considerable size. The rock at the Table is thin and composed of three bands, a white band between two of darker hue. To the south towards the Spit the light band appears to split into three, its central portion being darker. Part of this series was considered by Mr. Small to exhibit pyroclastic characters (1899–1909, p. 5).

The red rock of the Wick, Kittiwake Cave, the Neck, and Midland

---

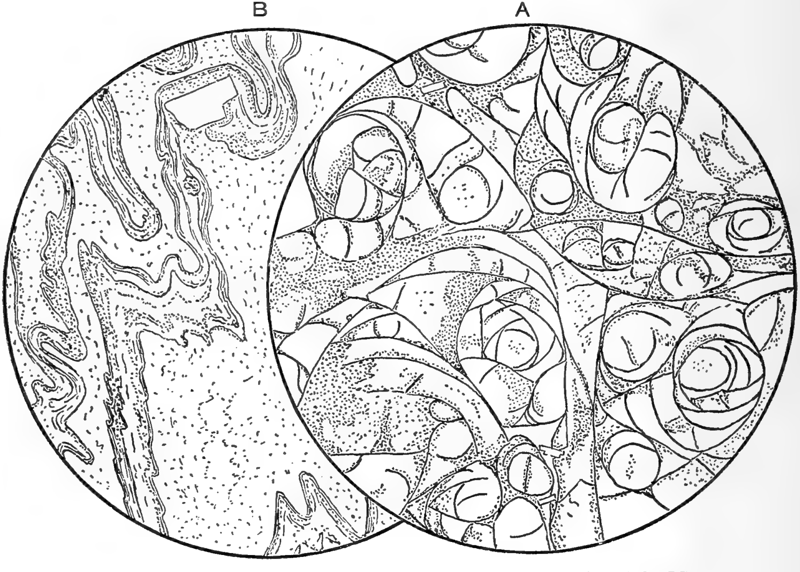
[1] A. Harker, 'Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. 1904, p. 15.

Island is also a thin mass, and in the hand-specimen shows no structure other than occasional flow-brecciation.

The Mewstone mass may be intrusive; it succeeds a series of quartzites, and its base is more glassy (fig. 3 A, below) than its higher portions. It is about 100 feet thick, and shows a roughly columnar structure towards the summit of the Mewstone.

The rhyolitic rocks of Musclewick on the mainland are similar to those of the North Cliff of Skomer, and are probably on the same volcanic horizon. Microscopically, the rocks range from cryptocrystalline devitrified obsidians to almost holocrystalline varieties presenting microlitic or even trachytic structures. The devitrified obsidians, such as those forming the base of the Mewstone and some bands in the northernmost mass, are beautifully perlitic (fig. 3 A), and occasionally, like some of the Tom's-House rocks, both perlitic and spherulitic. Flow-structures are almost constant features, and contortion of the flow-lines may be noticed both on the macroscopic and on the microscopic scale (fig. 3 B). On a large scale, these contortions are well exhibited above Tom's House.

Fig. 3.



A = Perlitic structure in the lowest part of the soda-rhyolite (?) of the Mewstone (Skomer). Slide E 7116.[1] × 25 diameters.

B = Contorted lines of flow in the soda-rhyolite of Bull Hole (Skomer); from a slide kindly lent by Mr. F. T. Howard. × 25 diameters.

---

[1] Where registration-numbers of slides are mentioned, these refer to the slides in the collections of the Geological Survey.

In the finely banded rocks, like those of the Basin, the bands are often not more than a millimetre in width, and appear as alternating light and dark layers. The light bands consist either of quartz, often with slender needles of apatite projecting inwards from the sides of the band, or of patches of alkaline felspar or coalesced spherules. The darker bands are composed of iron-stained cryptocrystalline felsitic material, almost isotropic, but with small patches of secondary felspar which appears to represent spherulites.

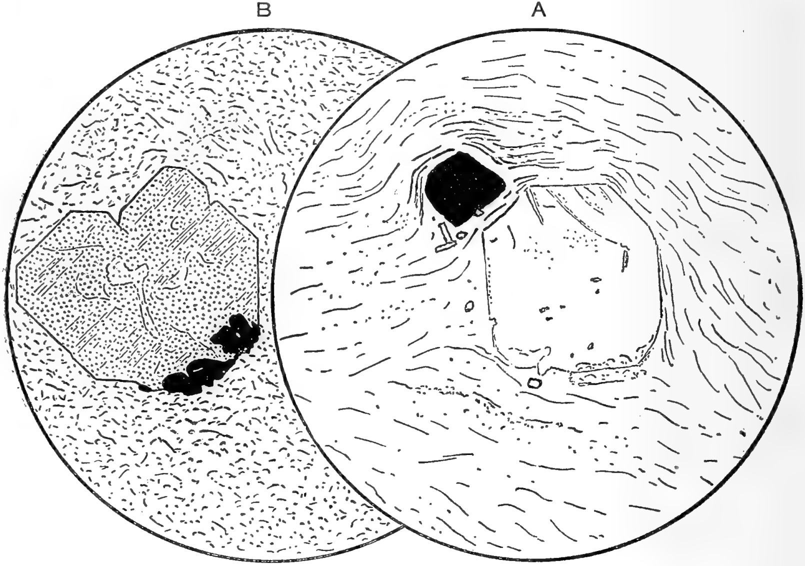
The coarsely spherulitic rocks of Skomer have received a fair share of attention since they were first described by Rutley in 1885, and are by far the best-known members of the Skomer Series. They are magnificently displayed on the coast between Tom's House and the Basin. The smaller spherules, those about the size of a pea or less, have a concentric structure towards the exterior, but the internal structure is fibrous and radiate. There is seldom any recognizable nucleus, and the felspar fibres radiate either from a central point or from a short line. The felspar has optically negative elongation, practically straight extinction, and low refractive indices.

Fig. 4.—*Nodular rhyolite of the Basin, Skomer Island.*

The spherules are usually white or grey, and are often collected in bands to form large axiolites, while a mammillated or botryoidal structure is sometimes observable on their surfaces. The big spherules are mostly solid spherulites, and are generally paler than the rock in which they lie. They range up to 9 or 10 inches in

diameter, and are distributed more irregularly than those of smaller size. They vary from perfect spheres to elliptical and disc-like masses flattened parallel to the flow-banding. Their surfaces are often ribbed or ridged parallel to the lines of flow, which may be traced across any internal structures. In cross-section they have a marked concentric (as well as radiate) structure; but there is evidence in many instances of hollow spaces, either concentric or more often central, which have been filled up with dark siliceous matter or secondary felspar. It has been argued that these hollow spaces were original, and that the structures are lithophysal. The proof of their secondary origin, however, lies in the fact that spherulites are seen which are composed of two parts—an outer felspathic layer, and an inner chalcedonic central portion. The outer layer is radiate, but the needles, if produced, would meet at the centre of the chalcedonic mass. The chalcedonic material radiates inwards from a series of points on the surface which separates the felspathic and chalcedonic portions of the spherulite. This clearly points to the removal of the central part of the original felspathic spherulite and its replacement by chalcedony. Some spherules contain a nucleus of cryptocrystalline silica or flint; and, in fact, Mr. Harker's description of the nodules in the Carnarvonshire

Fig. 5.



A = Pseudomorph after augite in secondary quartz and chlorite, in a purplish soda-rhyolite. Base of the North Cliff opposite the Garland Stone (Skomer). Slide E 7763. × 100 diameters.

B = Pseudomorph after augite in chlorite, in the soda-rhyolite (?) of the Mewstone summit (Skomer); from a slide kindly lent by Mr. F. T. Howard × 85 diameters.

rhyolites[1] might have been written for those of Skomer, with which he himself compares them. I agree with him in regarding these nodules, now often devoid of structure, as having been derived from simple spherulites by a process of alteration and substitution.

Phenocrysts are never present in large numbers in these rhyolitic rocks, and are often entirely wanting. When present they consist either of minute crystals of an acid plagioclase-felspar (between albite and oligoclase), or of microperthitic intergrowths. No potash-felspar has been detected, although the analysis of a rock from the Table (Analysis I, below) shows that potash is present in small quantity; it probably exists, therefore, in the groundmass, in the perthite, or in the phenocrysts in the albite-molecule, which may contain potash up to 16 per cent. of the total alkalies.

The albite-oligoclase crystals are usually twinned according to the Carlsbad and albite laws, but pericline lamellæ are rarely seen. Occasionally these rocks contain scarce and small chloritic and serpentinous pseudomorphs after some ferromagnesian mineral, such as those in the rocks of Manies Island and the island south-west of the Garland Stone, which appear to be after biotite; and those in the uppermost portion of the Mewstone mass, which appear to have the form of augite (fig. 5 B, p. 188). Sometimes, in rocks which have undergone secondary silicification, a mosaic of secondary quartz and chlorite occupies the cavity left by the decaying mineral (fig. 5 A, p. 188).

The groundmass of the devitrified obsidians is usually cryptocrystalline felsitic material, but in the more felspathic varieties it breaks up into irregular ill-defined patches of felspar, representing a type of devitrification common to many of the older rhyolitic lavas.

	I.	II.	III.
SiO_2	79·64	77·8	77·29
TiO_2	0·50	...	...
Al_2O_3	11·44	13·2	14·62
Fe_2O_3	0·11	0·2	trace
FeO	0·30	0·7	...
MnO	0·08	...	...
CaO	0·71	trace	...
MgO	0·15	trace	0·38
K_2O	0·38	2·1	0·16
Na_2O	6·40	5·1	7·60
H_2O at 105° C.	0·16	...	...
H_2O above 105° C.	0·30	...	...
P_2O_5	0·08	...	...
CO_2	0·02	...	...
Loss on ignition	...	0·6	0·57
Totals	100·27	99·7	100·62
Anal.	E. G. Radley.	F. H. Hatch.	F. H. Hatch.

I = Soda-rhyolite, near the Table, top of cliff, east of the Spit (Skomer). [Anal. No. 345, Slide E 7768.]

II = Soda-felsite, south-east of cairn on Castletimon Hill, Co. Wicklow (Ireland). Geol. Mag. 1889, p. 546.

III = Soda-felsite, Brittas Bridge, Co. Wicklow (Ireland). *Ibid.* p. 72.

---

[1] 'Bala Volcanic Series of Carnarvonshire' 1889, pp. 29 *et seqq.*

The accessory minerals are zircon, apatite, titaniferous iron-ore, magnetite, and pyrite, while common secondary minerals are granular sphene and chlorite. In some rocks (as, for instance, the Table felsite) the sphene is intensely pleochroic, like that of some metamorphic rocks, and has 𝔞 almost colourless, 𝔟 pale greenish, and 𝔠 deep reddish with 2 E about 63°. The chlorite is distributed through the base of the rocks, partly replacing felspars and infilling occasional vesicles.

All these rhyolitic rocks are evidently rich in silica and soda, and the analysis set forth on p. 189, of a rock forming a white and little altered band above the Table, is representative of the class. The analysis is of a rock which evidently consists almost entirely of quartz and albite; for its theoretical percentage composition would be orthoclase 2·2, albite 53·9, anorthite 1·1, and quartz 27·6. These rocks are closely allied to the soda-felsites of the South-East of Ireland, described by Dr. Hatch,[1] of which two analyses are tabulated for comparison. In the nomenclature of the American classification this rock would be designated westphalose, and placed in the persodic division of alaskase, a division containing the quartz-keratophyres of some authors.

The soda-rhyolites, with the assumption of a trachytic microscopic structure and an increased percentage of combined or free orthoclase, pass gradually into the albite-oligoclase trachytes described below.

(*b*) The Soda-Trachytes.

These rocks may be divided into three types:—

(1) Soda-trachyte, with little or no augite or hypersthene (for instance, Slides E 7029, 7122).
(2) Olivine-soda trachyte, with pseudomorphs after olivine (for instance, Slide E 7759).
(3) Hypersthene-soda trachyte, with pseudomorphs after hypersthene (for instance, Slide E 7148).

The first type is common and well represented on Skomer in the central belt of trachytic lavas which form a clearly-marked band across the island. The olivine-bearing rocks are best seen on Skomer and in the cliffs to the east of Martin's Haven.

The hypersthene-bearing type is represented on the mainland at Crabhall, north of Dale, where a large quarry has been opened for road-metal. In the hand-specimen all these rocks are somewhat splintery, grey in colour, and it is but exceptionally that they show any marked vesicular habit (for instance, Slide E 7485). They have only a few phenocrysts of sufficient size to be distinguished by the unaided eye. These rocks weather with a pale buff-coloured crust, which may extend for about half a centimetre into the rock.

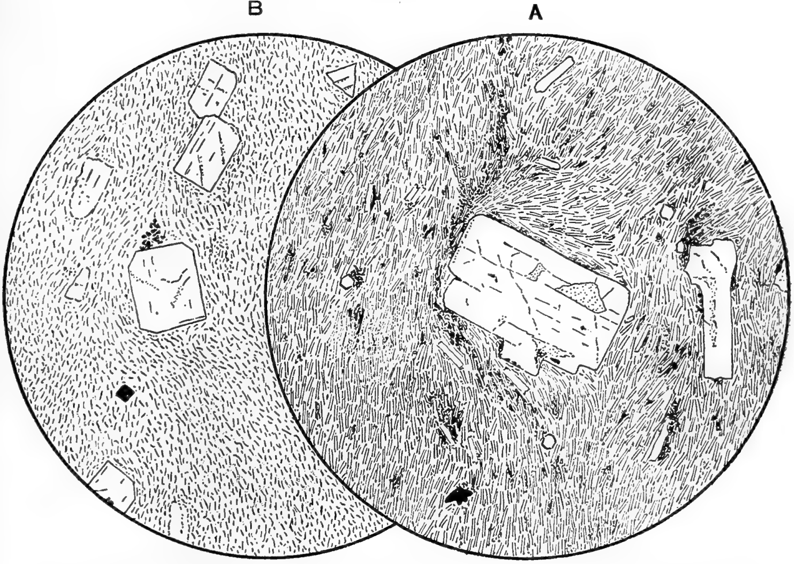
Under the microscope they are seen to consist of a few well-formed phenocrysts of albite, usually twinned, set in a mass of microlites of similar composition. The structure is typically trachytic.

---

[1] Geol. Mag. dec. iii, vol. vi (1889) pp. 70 & 545.

The phenocrysts in the finer-grained varieties (fig. 6, B, below) reach 2 mm. in length by about 0·7 in width, but the majority are smaller. The microlites in the same rock measure about 1 mm. in length by ·01 mm. in width; they are arranged in well-defined flow-lines, and enclose between them minute specks of chlorite and grains of iron-ore. In these rocks the rare vesicles (for instance, E 7029, 7285) are filled with a mosaic of quartz, and lined with a little chlorite; while the groundmass contains many granules of secondary sphene. In the rock figured below (fig. 6, A) the microlites are somewhat larger than usual, but the flow-structure is still beautifully preserved. Occasionally, as in this rock (E 7029), there occur small though undoubted pseudomorphs after augite; but the percentage of ferromagnesian mineral is always small. Apatite is not an uncommon accessory (fig. 6, A) and the iron-ore is titaniferous. These soda-trachytes show a family connexion with the keratophyres, in the restricted sense—into which they would pass by an increase in the size and basicity

Fig. 6.



A = Albite-trachyte from Captain Kite's Rock (Skomer). Slide E 7029, ordinary light. × 25 diameters.

B = Albite-trachyte, from low down on the North Cliff of Skomer, opposite the Garland Stone. Slide E 7122, ordinary light. × 25 diameters.

[Both these rocks show small phenocrysts of acid plagioclase-felspar set in a fine mass of acid plagioclase-microlites. The rock A shows well-shaped apatite-prisms.]

of the felspars, by the less complete development of flow-structure, and by assuming a more vesicular character.

The olivine-bearing rocks show in the presence of olivine their family resemblance to the marloesites (p. 198). They contain but little fresh granular augite, sometimes none; olivine, however, may be represented by pseudomorphs of considerable size (fig. 7, B, p. 193) in serpentine or chlorite. The ground-mass has a fine felsitic or trachytic character, and is composed of minute albite-oligoclase laths exhibiting a felted or fluidal arrangement. The felspar phenocrysts are albite or albite-oligoclase. In common with the marloesites (which see), these rocks often contain minute crystals and grains of a brown hornblende, similar to that detected by Mr. Harker [1] in the mugearites of Skye.

	IV.	V.	VI.
SiO_2	58·47	61·01	55·38
TiO_2	2·17	0·45	0·90
Al_2O_3	18·60	18·45	18·34
Fe_2O_3	1·92	2·09	1·13
FeO	4·77	0·80	5·86
MnO	0·19	trace	...
BaO	0·04	...	n. d.
CaO	0·99	1·91	3·25
MgO	0·94	0·94	3·47
K_2O	3·30	4·75	0·22
Na_2O	5·52	7·33	7·12
Li_2O	trace	...	n. d.
H_2O at 105° C.	0·50	3·09	0·48
H_2O above 105° C....	2·19		2·39
P_2O_5	0·45	...	trace
CO_2	0·04	...	2·00
Cl	0·02	...	n. d.
Totals	100·11	100·82	100·54
Anal.	E. G. Radley.	Deicke.	J. V. Elsden.

IV=Soda-trachyte (lava), North Cliff of Skomer, opposite the Garland Stone [Anal. No. 347, E 7769], same rock as E 7122.

V=Soda-trachyte? (block in tuff), Dachberg, Rhöngebirge. H. S. Washington [after F. Rinne], Prof. Paper 14, U.S. Geol. Surv. 1903, pp. 396–97.

VI='Lime-bostonite.' Abercastle (North Pembrokeshire). J. V. Elsden, Q. J. G. S. vol. lxi (1906) p. 596.

The hypersthene-bearing rocks (fig. 7, A, p. 193), or the Crabhall type [2] of soda-trachyte, have a ground-mass like that already described; but it differs in the inclusion of fairly large, stained, and striated prisms of apatite, and in the complete absence of granular augite. The bastite-pseudomorphs after the rhombic pyroxene measure up to 2 mm. in length, and the porphyritic albite-oligoclase felspars up to 8 mm. The bastite is surrounded by an opaque

---

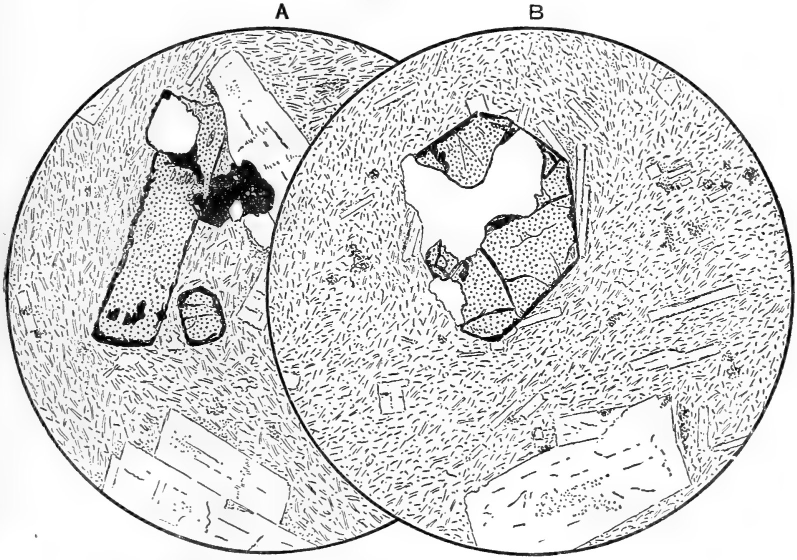
[1] 'Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. 1904, p. 262.

[2] J. J. H. Teall, 'British Petrography' 1888, p. 284 ['a somewhat basic porphyrite occurs at Crab Hole near Dale'].

border of iron-ores, and often includes granules of brown sphene (fig. 7, A, below). A certain amount of quartz in the ground-mass and also enclosing felspar-microlites appears to be original.

The fine-grained trachytic rock from the North Cliff of Skomer (andesite of Howard & Small) has been analysed (see Analysis IV, p. 192), and by its high percentage of alkalies evidently takes its place among the trachytes. The high percentage of potash was rather surprising, for, as in the case of the rhyolites, no orthoclase could be detected. The analysis would, however, suggest the presence of 19 per cent. of orthoclase, 46 per cent. of albite, and 5 per cent. of anorthite. Chemically, the rock compares fairly well with a soda-trachyte (Analysis V, p. 192) from the Rhöngebirge described by Prof. Rinne; but it differs considerably from the keratophyres, as represented by Dr. Elsden's 'lime-bostonite' (Analysis VI, p. 192).

Fig. 7.



A = Albite-trachyte, with pseudomorphs after a rhombic pyroxene; from Crab Hall Quarry, north of Dale. Slide E 7148, ordinary light. × 25 diameters.

B = Albite-trachyte, with pseudomorph after olivine. Cliff east of High Point, Marloes. Slide E 7759, ordinary light. × 25 diameters.

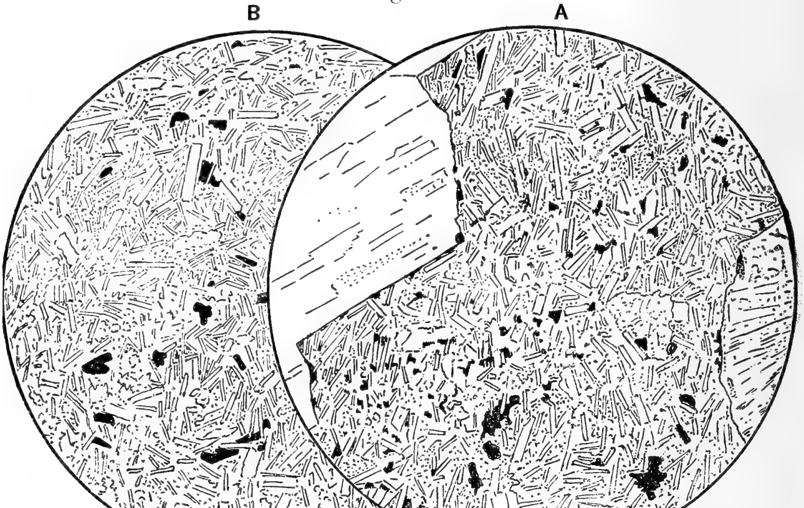
(c) The Keratophyres.

If the term keratophyre were used in the sense in which Prof. Rosenbusch uses it, all the rocks so far described would have been included thereunder; but it seems undesirable to include rocks which have always been regarded as rhyolites, and rocks which

present undoubted trachytic affinities despite the excess of soda over potash. Moreover, these more acid rocks are readily distinguished in the field from more basic lavas, which must be referred to as keratophyres. In this paper, therefore, the term keratophyre is restricted to those soda-rich lavas which would fall between the soda-rhyolites and the spilites, and differ chemically as well as structurally from the rocks hitherto described.

They are strongly represented on Skomer Island and the mainland, and are identical in most respects with the 'lime-bostonites' of Dr. Elsden,[1] which Prof. Rosenbusch[2] places with the keratophyres. In the case of Skomer the name 'lime-bostonite' seems unsuitable, for the rocks are certainly not intrusive like the similar rocks in North Pembrokeshire; nor is their structure that which is met with in typical bostonites.

Fig. 8.



A = Keratophyre with albite phenocryst and chlorite-filled vesicle. Above the soda-trachyte of North Castle (Skomer). Slide E 7024. × 25 diameters.

B = Keratophyre, non-porphyritic and non-vesicular. Below the soda-rhyolite of Bull Hole (Skomer). Slide E 7128. × 25 diameters.

As represented on Skomer and the adjoining mainland, they are fairly compact, grey to buff-coloured, somewhat speckled rocks, with

---

[1] Q. J. G. S. vol. lxi (1905) p. 594. I am indebted to Dr. Elsden for kindly placing at my disposal his type-sections of rocks from the Abercastle district of North Pembrokeshire.

[2] 'Mikroskop. Physiogr. d. Mineralien & Gesteine' 4th ed. vol. ii, pt. 2 (1908) p. 944. See also his 'Elemente der Gesteinslehre' 3rd ed. (1910) pp. 345–46.

conspicuous vesicles which are usually drawn out slightly in the direction of flow. These lavas were the most viscous of all but the rhyolitic rocks, and evidence of explosive outbursts may be gathered from the small patches of silicified pyroclastic material (for instance, E 7050) occupying hollows in the surfaces of the lavas (p. 185).

Porphyritic crystals of acid plagioclase are sometimes present, but seldom reach any considerable size. The ground-mass, as in the case of the trachytes, consists of lath-shaped microlites of albite-oligoclase felspars. The laths are usually well bounded, but in some cases they are somewhat indefinite, both as to their lateral boundaries and as to their terminations. They are usually twinned, sometimes only once, but more often if their breadth will allow of it. Flow-structures are not well shown, the structure being best described as 'felted.' The vesicles, which are numerous and large, are usually filled with chlorite, which may be either the ordinary feebly birefringent variety or the highly birefringent minerals allied to delessite. In both cases the material filling the cavity has a radiate structure. Occasionally the vesicles may be filled with secondary quartz (E 7111); but this is unusual, and probably represents surface-silicification. Granules of secondary sphene are abundant, and often good crystals project from the rock into the vesicular cavities.

Iron-ores in general are less common than in the soda-trachytes, but the felspars are often deeply iron-stained.

The felspar phenocrysts are albite-oligoclase, but are slightly more basic than those of the trachytes. Some appear to be microperthitic, and exhibit a curious vermicular structure, due presumably to the alteration or absorption of one constituent. They have, in most cases, suffered a fair amount of decomposition, giving rise to patches of calcite and less frequently epidote. Original ferromagnesian minerals are very rare, and almost always absent from these rocks.

The interstices between the microlites are filled with chlorite and a little cryptocrystalline material which might represent residual glass. Generally speaking, chlorite is not very plentiful in the ground-mass, but it may become a prominent constituent, and the same remark applies to the dusty iron-ores (E 7047).

In composition these rocks are evidently allied to the soda-trachytes, but differ chiefly in containing a greater amount of chloritic material and granular sphene, and structurally in the absence of well-defined fluxion-phenomena. They are so similar in mineralogical character and structure to Dr. Elsden's lime-bostonites that it was thought unnecessary to analyse them specially. Their composition will be approximately represented by the analysis of the Abercastle rock, tabulated on p. 192 (Analysis VI). It will be seen by comparing Analyses IV & VI that they are slightly more basic than the soda-trachytes and richer in lime and magnesia, but that the total alkalies approximate in value.

(*d*) The Skomerites.

A very prevalent rock-type on Skomer and the mainland is, as far as I am aware, peculiar to the district, and the name skomerite has therefore been applied to it.[1] The skomerites are compact, fine-grained, dark-grey rocks, with a tinge of green. They have a finely crystalline appearance, and show minute laths of felspar to the naked eye. They weather with a pale crust to a few millimetres in thickness, and are not so highly vesicular as the keratophyres.

Specimens collected from a flow beneath the Mewstone quartzites (E 7056) and from above the soda-trachyte of Pigstone Bay (E 7090) may be regarded as typical. These rocks consist of augite, olivine, albite-oligoclase felspars, accessory iron-ores, and secondary chlorite presumably replacing a fine-grained or glassy base.

The augite is a greenish variety, and makes a fifth to a quarter of the rock. It occasionally occurs in clots, but usually is evenly distributed as subidiomorphic crystals, grains, and subophitic patches, ranging up to 10 mm. in greatest dimension, but generally much smaller (fig. 9, A, p. 197). There are seldom more than two of the larger crystals in the area of any slide.

The subidiomorphic crystals and granules appear to belong to the same period of generation, and there was evidently but a very small time-interval between the consolidation of the various constituents. A few of the larger augites show slight resorption-borders, and many of the crystals are twinned, a feature which contrasts them with the augites of the olivine-basalts (p. 204).

Olivine is not an abundant constituent, but is usually present building small idiomorphic crystals about 0·3 mm. in length, pseudomorphous in dark green serpentine or strongly birefringent chlorite or iddingsite (?).

The porphyritic felspars are much decomposed and replaced by chlorite. They are generally not very well formed, and have their angles somewhat rounded. Their refractive indices are lower than that of balsam, and from the wide extinctions they would seem to be nearer to albite than to oligoclase. The felspars of the ground-mass are short ill-defined laths oriented in all directions, with little or no trace of fluidal structure. They have low refractive indices but small extinctions, and thus appear slightly more basic than the phenocrysts; they are still, however, on the albite side of oligoclase.

Iron-ores are scattered through the rocks as fine dust and as narrow plates; their quantity is very variable; and, judging from the relative abundance of secondary sphene, they are titaniferous. A few vesicles may be detected, and these are almost invariably filled with a mass of well-crystallized, secondary, water-clear albite, a little secondary quartz, and chlorite. Veins of these materials

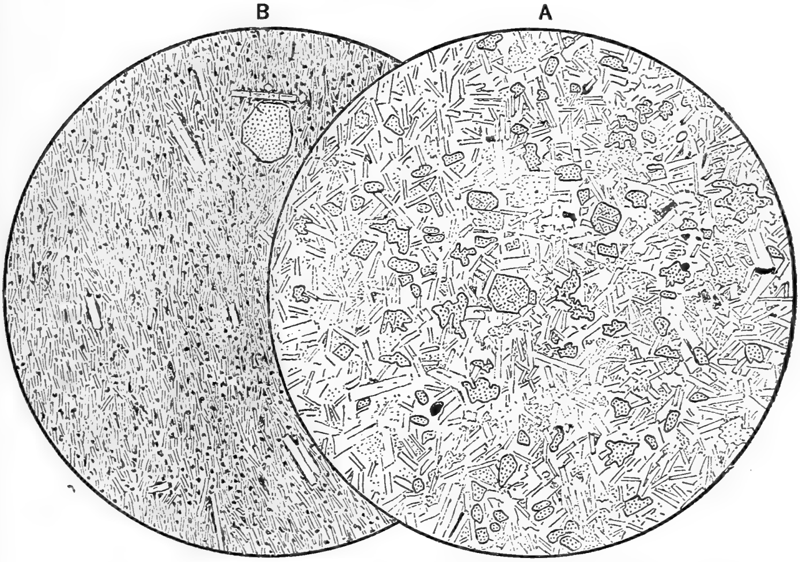
---

[1] This type is that which was described by Rutley (1881) p. 411, Slide No. 3, as basalt or andesite.

also cut the rocks locally. A little epidote may be present in the centre of some of the decomposed felspar-phenocrysts, and rarely fills vesicles. Apatite is a rare accessory.

Structurally, the rocks are in no way related to the andesites. With a decrease of ferromagnesian and porphyritic constituents (for instance, E 7046) and the assumption of a good fluidal structure (for instance, E 7112), they pass over in the direction of the mugearites; and by the occurrence of large olivines they approximate to the marloesites described below. An intermediate stage may be represented by a flow on the west side of Skomer Island, just above the North Cliff rhyolites (E 7097), which contains more olivine than the typical skomerite, but in smaller crystals than that of the marloesites.

Fig. 9.



A = Skomerite, showing subidiomorphic augite and albite-oligoclase felspar-laths; from the cliffs south of Pigstone Bay (Skomer). Slide E 7090, ordinary light. × 25 diameters.

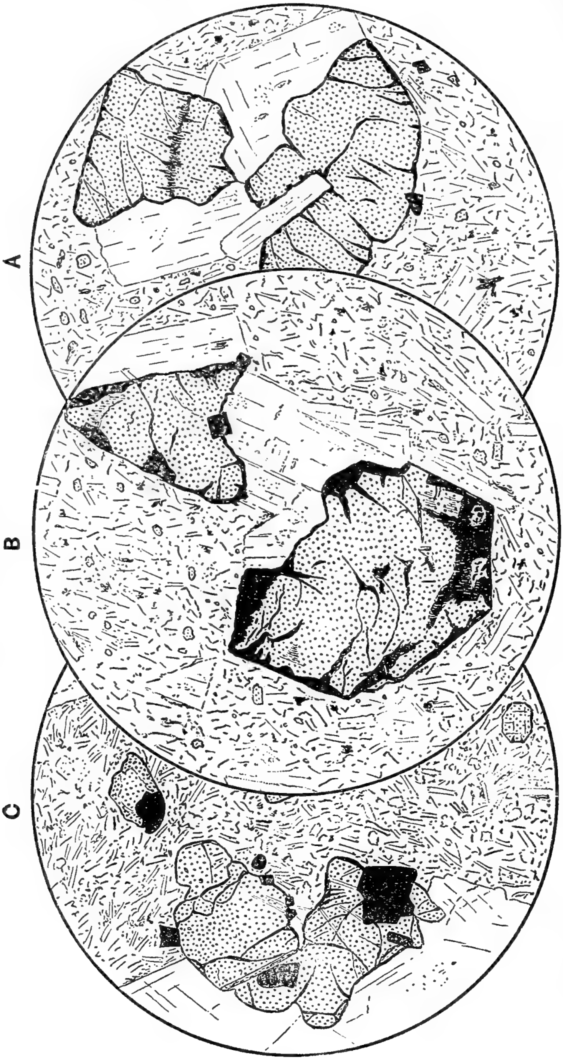
B = Mugearite, showing well-defined fluxion-structure, abundant iron-ores, and large apatite close to a small porphyritic augite-crystal; from 50 yards east of the Limekiln (Skomer). Slide E 7022, ordinary light. × 25 diameters.

Chemically, the skomerites would compare very closely with the marloesites (p. 200), from which they differ chiefly in the absence of the glomeroporphyritic groups of albite and olivine.

(*e*) The Marloesites.

These rocks take their name from the parish of Marloes on the mainland, where they are well represented. They occur at

Fig. 10.



A = Marloesite. Glomeroporphyritic crystals of albite and (pseudomorphs after) olivine, in a fine-grained ground-mass of albite-oligoclase felspar and augite. Crags south of Survey Station (Grassholm Island). Slide E 6993. × 25 diameters.

B = Marloesite, from the western side of the South Gut (Grassholm Island). Slide E 6995. × 25 diameters.

C = Pantellerite, with glomeroporphyritic intergrowth of olivine and anorthoclase, from the 'andesitic' series. Eastern flank of Montagna Grande (Pantelleria). Slide F 308. × 25 diameters.

Marloes Beacon, on the foreshore at Martin's Haven, at several localities on Skomer Island, and form the greater part of the southern side of Grassholm.

They are somewhat pale grey rocks, slightly mottled, very finely crystalline, and have a splintery fracture. They are compact and not conspicuously vesicular, except at their surfaces. They are clearly related to the skomerites, but contain conspicuous pseudomorphs after olivine—existing as deep red or bronze-coloured micaceous aggregates with a distinct sheen. These pseudomorphs range from 1 or 2 millimetres to a centimetre in width. Felspars are visible as narrow bright crystals, ranging up to a centimetre and a half in length, but usually not more than half a centimetre. The rocks weather with a pale crust, and are often streaked with hæmatite in bands 3 to 4 millimetres wide.

Microscopically they show a glomeroporphyritic structure, and consist of olivine and acid plagioclase-phenocrysts set in a relatively fine-grained ground-mass containing much augite, acid plagioclase, and accessory iron-ores. The olivines, which are usually intergrown with the larger plagioclase-crystals (fig. 10, A & B, p. 198), have a tendency towards idiomorphism. They are nearly always represented by pseudomorphs in serpentine, ferrite, or a bright-green pleochroic mineral[1] produced by the re-absorption of the external coating of iron-ores. They are only very occasionally replaced by calcite (E 7037).

The porphyritic felspars are albite-oligoclase; they are usually twinned on the Carlsbad and albite laws, and show incipient decomposition to micaceous aggregates, which render them turbid. Some of the felspars are perthitic.

The ground-mass, of which the structure lies between intersertal and trachytic, is composed of felspar-microlites enclosing between them small but abundant subidiomorphic crystals and granules of augite. Some of the latter mineral, however, as in the skomerites, behaves ophitically with respect to the felspar-microlites. The microlites are comparable in every respect to those of the skomerites (p. 196), but occasionally may be arranged in curling flows around the larger individuals.

In these rocks there is present, in fair quantity, a brown, probably soda-bearing, hornblende identical with that mentioned as occurring in the olivine soda-trachytes (p. 192). It has the following pleochroic scheme :—$\mathfrak{a}$, pale reddish-brown ; $\mathfrak{b}$, pale brown ; $\mathfrak{c}$, pale yellowish-brown. The plane of the optic axes lies in the plane of symmetry, $\mathfrak{c}_\wedge c' = 24^\circ$ approx.; it is optically positive, and $2\,E$ is greater than 120°. The birefringence is distinctly low, being considerably less than that of the augite in the same rock. The mineral occurs in small crystals and grains in the ground-mass, but occasionally is found within some of the porphyritic felspars (E 6996). It shows the characteristic hornblende-cleavages.

The vesicles of these rocks are usually small, and filled either with secondary quartz and chlorite or with interlocking prisms of

---

[1] This mineral is green for light vibrating parallel to the cleavages, and yellow for the direction at right angles. The cleavage-traces mark the positive direction.

clear albite. On Grassholm Island in the South Gut a dark-green ferruginous epidote occupies the cavities in one of these lavas. Mineralogically, these rocks are related to the skomerites, from which they differ chiefly in the large proportion of olivine and in the presence of the brown hornblende. They are also related to the olivine-soda trachytes, which differ from them in containing little or no augite and possessing a trachytic ground-mass.

Compared with rocks of other districts, they present several points of resemblance to some of the less acid rocks of Pantelleria, described by Foerstner,[1] which stretch from the Montagna Grande to Monte Gibelé. One of these rocks has been figured for comparison with the marloesites (fig. 10, C, p. 198). It shows large badly-formed olivines (between true olivine and fayalite) in association with anorthoclase. The other porphyritic constituent is a pale monoclinic pyroxene, and the ground-mass contains many subophitic grains of augite, as also a good deal of cossyrite. The brown hornblende of the marloesites, if original, might be taken as representative of the cossyrite of the Pantellerian rocks.

	VII.	VIII.
SiO_2	52·37	49·80
TiO_2	1·16	1·73
Al_2O_3	18·05	16·24
Fe_2O_3	3·40	3·85
FeO	4·27	5·31
MnO	0·28	0·27
(CoNi)O	not fd.	0·02
BaO	0·02	0·02
CaO	6·18	4·01
MgO	5·53	4·52
K_2O	1·97	2·51
Na_2O	4·36	4·88
Li_2O	trace	trace
H_2O at 105° C	0·32	1·08
H_2O above 105° C.	1·83	2·43
P_2O_5	0·18	0·18
CO_2	0·17	3·22
Totals	100·09	100·07
Anal.	E. G. Radley.	E. G. Radley.

VII=Marloesite, lava-flow; south side of Grassholm Island. [Anal. No. 330. Slide E 6995.]

VIII=Marloesite, lava-flow; foreshore, east side of Martin's Haven, Marloes (Pembrokeshire). [Anal. No. 343. Slide E 7753.]

Chemically (see Analyses VII & VIII, above), the marloesites appear to be derived from a magma which differed but little from that of the mugearites (see Analysis XII, p. 202), except in the smaller percentage of iron-oxides and the greater percentage of magnesia: pointing to a smaller proportion of iron-ores and an

---

[1] 'Geologia dell' Isola di Pantelleria' Boll. R. Comit. Geol. Ital. vol. xii (1881) p. 523.

increase in the bisilicates. The percentage of phosphoric acid is much lower. The alkalies are fairly high, and, considering the potash as present in the albite-molecule, their percentages would indicate the presence of 48 per cent. of albite.

The apatite content is only 0·3 per cent. in the least altered rock.

(*f*) The Mugearites.

The mugearites form a well-defined group which, although constant in structural characters, presents some variation in chemical composition. In this group are placed typical mugearites with oligoclase as the dominant felspar, but there are others in which the felspars may be more acid or more basic. Those with more acid felspars pass in the direction of the keratophyres and soda-trachytes, and those with more basic felspars in the direction of the fluidal olivine-basalts (p. 203).

All these rocks are generally but slightly vesicular, though some contain vesicles measuring up to 4 or 5 mm. in diameter (E 7078). They are dark grey, streaked with red, and show a finely crystalline structure. They weather to a pale grey or buff, and their surfaces are often red-stained. The true mugearites, as developed in the Skomer Series, consist of a mass of oligoclase-microlites, arranged with well-defined flow-structure, and a few laths of somewhat larger size with their axes parallel to those of the microlites (fig. 9, B, p. 197). The laths average 0·3 millimetre in length, and have somewhat indefinite terminations.

The ferromagnesian minerals consist of numerous green serpentinous pseudomorphs (well shaped) after olivine, and small idiomorphic crystals of a strongly coloured augite. Augite also exists as minute grains between the microlitic felspars. Iron-ores are abundant, and from the number of regular sections appear to be magnetite; but the prevalence of granules of secondary sphene would point to the presence of the titaniferous variety of that mineral.

Typical samples were collected from the crags north-east of the Limekiln, Skomer Island (E 7022, 7023), and from the crags 200 yards south of the flagstaff (E 7107).

In many rocks of the mugearitic series both augite and olivine are present in about equal proportions, but in others either olivine or augite may be developed in excess. In a rock (E 7030) from South Haven north of the Seal Hole, olivine alone is represented by small idiomorphic crystals (pseudomorphs of calcite) with their axes parallel to the lines of flow; also a few of the felspar phenocrysts are more basic than those of the ground-mass. In the acid direction, by the diminution of the ferromagnesian constituents, they pass into rocks characterized by a few augite and olivine-phenocrysts, but otherwise allied to the keratophyres (for instance, E 7059). The felspars at the same time become more acid than typical oligoclase. In the basic direction, if the augite and olivine increase in amount, the felspars approach labradorite, but are

still more acid than they should be in a normal basaltic rock. There is no doubt that these basic mugearites pass gradually into a group of olivine-basalts which have well-defined fluxion-structure and a general absence of phenocrysts. Of these more basic mugearites I may mention rocks from south of the Flagstaff, Skomer (E 7767, Analysis IX, below), and from just above the sediments in South Haven (E 7014).

	IX.	X.	XI.	XII.
SiO_2	50·19	49·24	49·29	50·06
TiO_2	2·72	1·84	2·27	2·46
Al_2O_3	14·57	15·84	16·66	15·72
Fe_2O_3	4·39	6·09	7·24	3·94
FeO	8·96	7·18	4·81	7·63
MnO	0·32	0·29	0·55	0·30
(CoNi)O	not fd.	...	0·04	0·03
BaO	0·03	0·09	...	0·03
CaO	7·60	5·26	5·63	5·90
MgO	2·79	3·02	2·42	3·82
K_2O	1·53	2·10	1·86	2·16
Na_2O	4·24	5·21	4·98	4·55
Li_2O	trace	...	...	not fd.
H_2O at 105° C.	0·32	1·08	0·34	0·67
H_2O above 105° C....	1·54	1·61	2·11	1·36
P_2O_5	1·12	1·47	0·24	0·64
FeS_2	0·03	...	...	nt. fd.
CO_2	0·02	...	2·32	1·08
Cl	0·05	...	...	0·04
F	...	0·18	...	...
S	...	0·03	...	...
	100·42	...	...	100·39
Less O for Cl	0·01	...	...	0·01
Totals	100·41	...	...	100·38
Anal.	E. G. Radley.	W. Pollard.	W. Pollard.	E. G. Radley.

IX=Mugearite (lava); south-east of the House (Skomer). [Analysis No. 346. Slide E 7767.]

X=Mugearite (intrusion); Skye. [Analysis No. 263. Slide S 13250.]

XI=Mugearite (lava); quarry, Corston Hill, Corston (Midlothian). [Analysis No. 247. Slide S 12710.]

XII=Mugearite-basalt (lava); hilltop, half a mile north-east of Balhennan, 9 miles south-west of Stirling. [Analysis No. 338. Slide S 14130.]

As regards mineral constituents and chemical composition, the rocks of this group compare quite well with the mugearites of Mr. Harker, and therefore they have been classed as such, although there is little doubt that the Skomer rocks are extrusive and not intrusive like the mugearites of Skye.

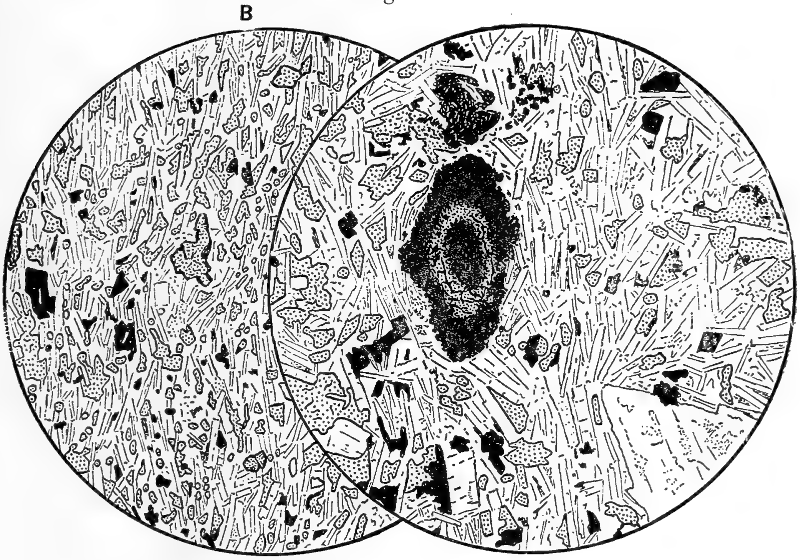
It will be seen from the analysis of the somewhat basic mugearites (E 7767) that the felspar is on the labradorite side of true oligoclase, and in this respect the rock approximates to the basalts; but in all other characters, such as the high percentage of iron-ores, the low percentage of magnesia, and the fairly high percentage of phosphoric acid, it compares well with the type.

Structurally, and in the mineral contents, the agreement is close, except in the absence of the brown hornblende and mica from the Skomer rocks

(*g*) The Olivine-Basalts.

The basalts are dark compact rocks, vesicular in their upper and lower portions, with a finely crystalline aspect and a purplish tinge (due to the somewhat deeply coloured augite which they contain abundantly). They are all of the granulitic or hypidiomorphic type, and consist essentially of magnetite, olivine, augite, and basic plagioclase.

Fig. 11.



A=Olivine-basalt, porphyritic, showing porphyritic labradorite and corroded and decomposed olivine-phenocrysts; from the cliff south of Bull Hole (Skomer). Slide E 7480, ordinary light. × 25 diameters.

B=Olivine-basalt, non-porphyritic, with well-developed fluxion-structure and granular augite; from inland crags south of the North Cliff rhyolite (Skomer). Slide E 7102, ordinary light. × 25 diameters.

This may be divided for purposes of description into two types which merge insensibly one into the other: (*a*) a porphyritic type, with porphyritic plagioclase and a ground-mass usually devoid of flow-structure (fig. 11, A, above); and (*b*) a non-porphyritic type, with beautifully developed flow-structure (fig. 11, B).

The porphyritic felspars are all much decomposed, passing into micaceous aggregates and being replaced by chlorite. They appear to be a labradorite of medium composition, and in extreme cases reach 1 cm. in length, but more often measure about 5 mm.

Their boundaries are sharp, they are frequently zoned, and occasionally include grains of augite (for instance, E 7480). Augite is plentiful, and exists as subidiomorphic crystals, glomeroporphyritic groups, and sometimes (as in E 7026) as fairly large idiomorphic crystals penetrated by, but not ophitically enclosing, laths of felspar. The greater part of the augite exists as small granules involved in the plexus of felspar-laths which form the bulk of the ground-mass. These felspars usually are perfectly fresh: they average 0·3 or 0·4 mm. in length, and are generally twinned according to the Carlsbad law. They may show repeated albite-lamellation if their width allows of it. Their high refractive indices and wide extinction indicate a labradorite about Ab_1An_1—that is, slightly more acid than that of the phenocrysts.

The olivine usually exists as small idiomorphic crystals in the ground-mass, about 0·2 mm. long; but occasionally a single partly absorbed individual may reach 2 mm. in length (fig. 11, A, p. 203). This mineral is always represented by pseudomorphs, either in limonitic iron-ores, or in chlorite, serpentine, calcite, iddingsite, and the green pleochroic mineral mentioned above (p. 199).

The iron-ores are well defined, and, from the number of regular sections, they would appear to be magnetite or titanomagnetite, probably the latter. There is little or no residual matter, but in some of the rocks a certain amount of glassy base seems to be represented by interstitial chlorite which is devoid of the other rock-constituents. The vesicles never contain zeolites, but are filled with calcite, secondary silica, chlorite or epidote, and often lined with sphene (for instance, E 7079). Between the porphyritic and the extremely fluidal types of basalts is a set of rocks (for instance, E 7058, 7480, etc.) which exhibit practically no porphyritic felspars, the porphyritic individuals being represented by a few laths of larger size. All the augite is granular, and the olivine pseudomorphs are of small dimensions.

The extremely fluidal rocks, of which there are many examples, are identical in composition with those just described, but differ in the felspar-laths and plates being slightly smaller in size and arranged in parallel streams. In a few of these rocks (as, for instance, E 7049) the felspars are near to andesine in composition, and thus they show affinities with the mugearites. These rocks are prevalent at the Smalls, and might be classed as mugearitic basalts.

An analysis (Analysis XIII, p. 205) of a typical non-porphyritic Skomer basalt shows that these rocks are somewhat less basic than the average olivine-basalt, the silica being about 6 per cent. higher. Also there is a slight falling-off in the percentage of lime, magnesia, and iron, with a correspondingly small increase in the alkalies: pointing to a labradorite-felspar of less basic composition, less augite, and less iron-ore. However, the rocks are sufficiently basic to be classed with the basalts, and show no tendency to pass into rocks which might with any consistency be termed augite-andesites. According to the classification of Whitman Cross, Iddings, etc., the

	XIII.	XIV.	XV.
SiO_2	53·82	52·68	52·13
TiO_2	1·66	...	not dt.
Al_2O_3	14·70	14·14	14·87
Fe_2O_3	2·39	1·95	not det.
FeO	6·74	9·79	11·40
MnO	0·39	0·44	0·32
(CoNi)O	0·03	n. d.	...
BaO	0·02	n. d.	...
CaO	9·03	9·38	10·56
MgO	4·84	6·38	6·46
K_2O	1·85	0·87	0·69
Na_2O	2·75	2·56	2·60
Li_2O	not fd.	...	...
H_2O at 105° C.	0·37	1·60	1·19
H_2O above 105° C.	1·59		
P_2O_5	0·10	...	not det.
CO_2	0·10	...	...
Totals	100·38	99·79	100·22
Anal.	E. G. Radley.	G. W. Hawes.	A. Streng.

XIII = Granulitic basalt (lava); above the Limekiln (Skomer). [Analysis No. 344. Slide E 7766.]

XIV = Dolerite (diabase); Mount Holyoke, Mass. (U.S.A.). G. W. Hawes, Amer. Journ. Sci. ser. 3, vol. ix (1875) p. 186.

XV = 'Trap'; Giants' Causeway (Antrim). Pogg. Ann. vol. xc (1853) p. 114.

rock of which the analysis is tabulated above would be designated auvergnose (Symbol III, 5 . 4 . 3), and would take its place among a series of extrusive and intrusive rocks, of which the dolerite of Mount Holyoke approximates most closely to it in chemical composition (Analysis XIV); while certain rocks at the Giants' Causeway, Antrim, resemble it in many respects (Analysis XV).

A striking difference between the Skomer rocks and many of the Tertiary flows of other regions is the complete absence of zeolitization, for no zeolites have as yet been detected infilling the vesicles of Skomer basaltic rocks. The cavities are always filled with what would be regarded as the normal products of weathering, such as chlorite, epidote, etc.

(*h*) The Olivine-Dolerites.

These rocks are not of very frequent occurrence, but are of wide vertical and horizontal distribution. They occur at the southern end of the Smalls; on Skomer in Pigstone Bay above the sediments, and in the cliffs above the Table, in South Haven above the sediments, and associated with sediments at the bottom of Matthew's Wick; on the mainland at Hopgang.

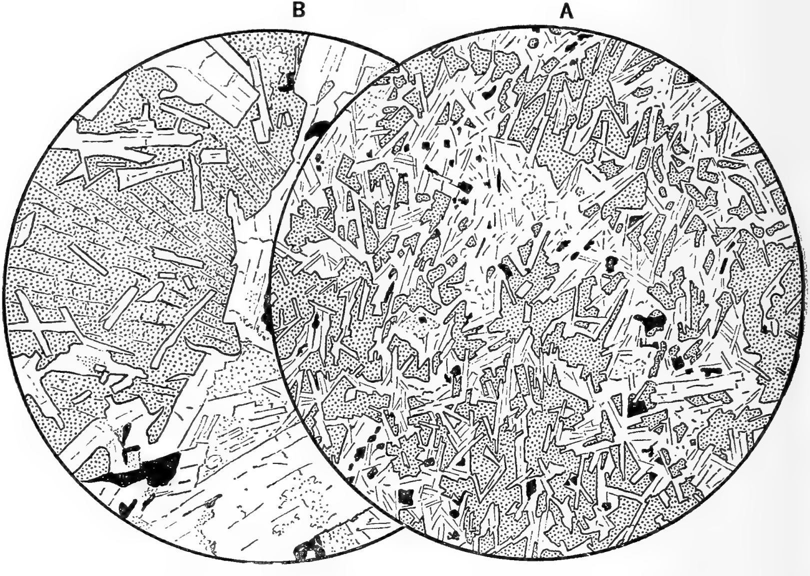
They exist as masses of much greater thickness (20 feet) than is usual for the flows; while microscopically they present all the appearances of intrusive rocks, with the exception of chilled margins.

In the hand-specimens they are more compact and less vesicular

than the older basic and intermediate rocks, but the vesicles are larger and not confined to the margins of the sheets. They often immediately succeed beds of red clay, or some other sediment which shows no noticeable induration at the contact.

Although their intrusive nature is open to doubt, I am led to regard these dolerites as intrusions on the following grounds:—(1) their limited occurrence and striking dissimilarity to all the other rocks of the series; and (2) their thickness and their indiscriminate association with rocks of widely different types. The association of dolerite sheets with beds of red clay and the absence of any important metamorphic effect are points commented upon by Mr. Harker in connexion with the basic sills of the Western Isles of Scotland.[1]

Fig. 12.



A=Typical ophitic dolerite of the Skomer Series; below the acid series of the Table (Skomer). It rests upon a bed of red and green mudstone, 2 feet thick. Slide E 7118, ordinary light. × 25 diameters.

B=Coarse ophitic dolerite; from the Anvil, the south-western point of the Wooltack peninsula. Slide E 7755, ordinary light. × 25 diameters.

The dolerite of Anvil Point is regarded as a lava, for it is succeeded by a bed of red clay which has evidently been formed in part from the igneous rock beneath.

Under the microscope the Skomer dolerites are finely crystalline rocks, consisting of labradorite laths, similar to, but slightly more basic than, those of the basalts, sometimes with a tendency to stellate grouping, enclosed ophitically by clots of purplish augite.

---

[1] 'Small Isles of Inverness' Mem. Geol. Surv. Scotl. 1908, p. 59.

These clots are circular or elliptical in outline, are separated from each other, and measure up to 3 mm. across.

The olivine exists as minute serpentinous pseudomorphs exhibiting borders of iron-oxides. Iron-ores with regular sections are plentiful, and apatite is an abundant accessory.

The coarse dolerite (fig. 12, B, p. 206) consists of a pale purple augite in ophitic plates, with laths and lath-shaped porphyritic crystals of labradorite-felspar. It contains fairly large pseudomorphs after olivine in serpentine, chlorite, and delessite, or the green micaceous mineral mentioned above (p. 199), veins of which also traverse the rock.

Chemically, the Skomer dolerites are closely related to the Jedburgh type of dolerite of Central Scotland, described by Prof. W. W. Watts[1] and later by Mr. E. B. Bailey,[2] and would have a silica-percentage of about 46. The titanium, iron, lime, and magnesia would all be high, but the percentage of phosphoric acid is probably greater than in the Jedburgh dolerites.

Structurally, the Skomer rocks are almost identical with a rock from a point 700 yards west of Dumbeath, Stirling Castle (S 12568), but are slightly less rich in olivine.

VI. The Associated Clastic Rocks.

The sediments associated with, and occurring within, the Volcanic Series form one main group, about 450 feet thick, which stretches in a strong ridge across Skomer (see map, Pl. XI). These rocks are thrown northwards by a fault which passes from South Haven to North Haven and between the Rye Rocks. On the mainland these sediments form a much-faulted belt near the northern coast between Martin's Haven and Hopgang, and also occupy Cable Bay and Mouse's Haven in the Wooltack peninsula. They are well exposed on Skomer in the Wick, at Welsh Way and at the base of Highcliff, in North and South Havens, and at Protheroe's Dock on the north side of the Neck. They consist, in the lower part, of coarse rhyolitic breccias and conglomerates alternating with white, buff-coloured, or green quartzites; in their upper part, they consist of alternating quartzites and red clays—the latter becoming predominant at the top. These red clays are exceptionally well displayed in the sections at the Wick, South Haven, and Protheroe's Dock.[3]

Quartzites belonging to other horizons in the series occur in the extreme south of Skomer and in the Mewstone Channel; below the dolerite of Pigstone Bay and the trachyte of North Castle; at South Castle on the Neck; on the south side of Midland Island; on the north side of the Deer Park at Wooltack; on the high ground west of Martin's Haven; and as a thin band on the northern coast

---

[1] In Sir Archibald Geikie's 'Ancient Volcanoes of Great Britain' vol. i (1897) p. 418.

[2] 'Geology of the Country around Glasgow' Mem. Geol. Surv. [in the press].

[3] For a detailed description of these sections, see E. W. Small, 1899–1909, pp. 12–13.

between Martin's Haven and Hopgang. A beautiful rhyolitic conglomerate is exposed on the shore in the west side of Martin's Haven. I have been unable to prove the existence of grits in the Garland Channel (Skomer), as suggested by Mr. Small. All the half-tide rocks examined were of rhyolitic character; but some were well bedded, and presented the appearance of sediments when looked at from the top of the cliff.

Red clays on other horizons are frequent, and occur in Pigstone Bay, below the rhyolite of Tom's House; at South Castle; a little way below the red rhyolite of the Neck and Midland Island; in Mouse's Haven; and in association with the dolerites of the Anvil.

All these rocks were undoubtedly deposited by water, and, although the red clays, which range from 1 to 7 feet in thickness, are similar to the boles of other districts and are undoubtedly due to the weathering of basic lavas, they have not been found in place except in a few instances, but have been deposited by water, as is shown by the common occurrence of spangles of mica. The upper portions of the flows on which they rest occasionally appear to be roughly conglomeratic, the igneous fragments being deeply stained and interbedded in a red clay matrix (as, for instance, Pigstone Bay, the south side of Midland Island, and the upper dolerite of the Anvil). The red clays present the most conclusive evidence of the subaërial character of the igneous rocks, and for the most part are associated with the more basic members of the Volcanic Series. Even when the clays are absent, many of the lava-surfaces show a conspicuous red staining, such as is noticeable on the south side of Grassholm, and on the dip-slopes of Skomer Head, the Neck, and Wooltack Head.

Examined microscopically, the rhyolitic breccias of the main sediments of Skomer Island might be described as arkose, almost all the fragments, which measure as much as 7 inches across, being of igneous origin. These fragments consist of pieces of soda-rhyolite, broken spherulites, keratophyres, soda-trachytes, and other Skomer rocks, in a fine felspathic matrix consisting of quartz and broken crystals of plagioclase.

The finer sediments range from felspathic grits to quartzites. They are made up of subangular quartz, angular soda-rich felspar, and a few fragments of trachytic and other acid volcanic rocks set in a more or less silicified clastic matrix.

True pyroclastic rocks, as has been remarked (p. 185), are very poorly represented in the Skomer Series. One of the best series of tuffs is that exposed in Pigstone Bay. The rocks are well bedded, reach 8 feet in total thickness, and consist of numerous broken acid-plagioclase crystals, as also fragments of perlitic, spherulitic, and microlitic rhyolites, set in a highly felspathic paste composed largely of felspar fragments and microlites. The small patches of silicified clastic material on the surfaces of certain of the keratophyres have already been mentioned (p. 185).

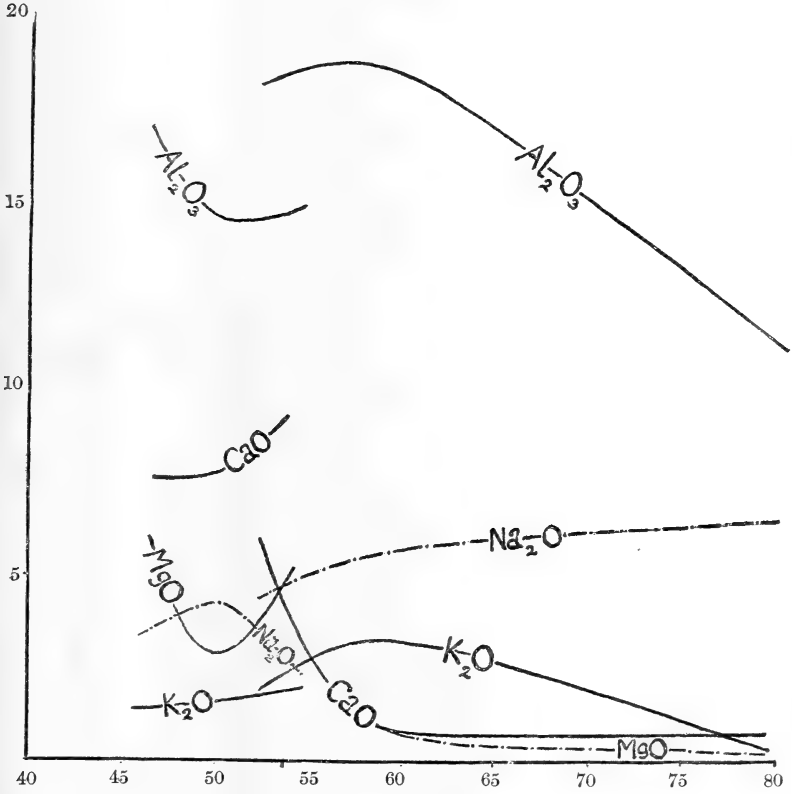
On the mainland tuffs of intermediate character and several feet thick have been noted beneath the quartzites of Cable Bay in the cliffs of Wooltack.

VII. The Chemical and Mineralogical Composition of the Lavas.

Chemically and mineralogically, the rocks of the Skomer Series show some marked peculiarities. Primarily they form a group rich in soda and poor in lime, a fact which shows itself in the prevalence of soda-rich plagioclase felspars.

The abundance of soda-rich felspars and the unusual character of many of the rocks might reasonably, in view of recent research, suggest that some of the rocks were originally more basic, but had undergone a process of albitization similar to that described by Messrs. Bailey & Grabham.[1] In the Skomer Series, however, if albitization has taken place, it has been complete and has left no trace of intermediate stages as an indication of the change. Again, if the rocks are albitized, albitization has been restricted to certain

Fig. 13.—*Diagram illustrating the percentage chemical composition of the Skomer igneous rocks.*



---

[1] Geol. Mag. dec. 5, vol. vi (1909) p. 250.

flows and groups of flows: for rocks with much albite are often to be found between flows of which the felspar is all labradorite. Also the rocks rich in albite, as regards structures and the nature and arrangement of the ferromagnesian minerals, are quite different from the more basic rocks which presumably would represent their unaltered prototypes. Secondary albite, when it does occur in these rocks as veins and infilling vesicles, is, as usual, water-clear and quite different from the felspars of the phenocrysts, etc., which show turbidity due to incipient decomposition. I am led, therefore, to regard the chief mineralogical and chemical peculiarities of the Skomer rocks as primary, and to consider the Series in part to be rich in original soda and to present Pantellerian affinities. The Series, as a whole, may be regarded as a curious interdigitation of alkaline and subalkaline types.

The accompanying diagram (fig. 13, p. 209) makes it appear that the rocks represented are a mixture of types converging in the basic direction, for the analyses when plotted seem to indicate that the rocks belong to two distinct but overlapping series.

The dolerites and basalts may be considered normal augite-labradorite rocks; but all the other igneous rocks show mineralogical and structural peculiarities, the most remarkable of which is the widespread occurrence of albite and albite-oligoclase felspars in intimate association with large porphyritic crystals of olivine, as in the olivine-trachytes and marloesites, and with abundant augite in the skomerites.

Another peculiarity worthy of note is the occurrence of the brown hornblende in the olivine-trachytes and marloesites. In the more acid rocks the felspars are hardly ever zoned, but are sometimes beautifully microperthitic—features which are common in rocks of the alkaline class. There are no felspathoid minerals or zeolites.

VIII. The Sequence in Time of the various Rock-Types.

The sequence presented by the Skomer Series, as made out on the mainland of Pembrokeshire, differs somewhat from that observable on Skomer Island; but the differences may be explained by the eastward thinning of the series as a whole and the overlapping of certain horizons by others. Considering the mainland, the lowest member of the series is a group of rhyolites exposed at Musclewick beyond the eastern edge of the map (Pl. XI), and followed presumably by the mugearitic group of Wooltack Head. This in turn is succeeded by the intermediate group of the northern cliffs which underlies the main sedimentary group. The highest rocks consist of olivine-basalts, and overlie the sediments. The general succession, therefore, is from acid to basic.

On Skomer Island a much greater thickness of volcanic rocks may be studied. The lowest rocks visible are those of the rhyolitic group of the mainland, which here reaches some 500 feet in thickness. It is followed by an insignificant group of intermediate

rocks which give place to the lower basalts, about 220 feet thick. These basic rocks are followed by the main group of intermediate lavas, represented by skomerites, keratophyres, and trachytes. There is then a return to basic conditions, as testified by the great mass of mugearites and basalts which occupies the centre of the island. A glance at the map will suffice to show that there appears to be a regular succession from acid to basic, and then back again from basic to acid rocks in a rhythmic sequence. Important rhyolitic groups occur at four horizons, and in almost every case are led up to by increasingly acid, and followed by increasingly basic rocks.

It will be seen, therefore, that where the greatest thickness of igneous rocks can be studied there is a frequent repetition of types without any abrupt change in the character and composition of consecutive flows. These abrupt changes, however, become more and more obvious as the distance from the vent increases, and as thinning and overlap within the series become more pronounced.

IX. Summary and Conclusions.

The Skomer Volcanic Series, which takes its name from Skomer Island off the coast of West Pembrokeshire, has a minimum thickness of 2900 feet and a lateral extension of over 26 miles from east to west, from the neighbourhood of St. Ishmael's, on Milford Haven, to beyond the Smalls in St. George's Channel. The positive evidence places the age as pre-Upper Llandovery, but the indirect and negative evidence would suggest that the volcanic rocks belong to the lower part of the Arenig Series. The rocks are for the most part subaërial lava-flows of extreme thinness and great lateral extent. The subsequent intrusive phase is but feebly represented by a few dolerite sills, and possibly by a mass of soda-felsite.

There is a paucity of true pyroclastic rocks, but sediments in the form of breccias, conglomerates, quartzites, and red clays, with a total thickness of 450 feet, mark a constant horizon near the centre of the series. The red clays which also occur on other horizons, although partaking of the nature of plinthite, are not in most cases formed by the decomposition of the basic rocks in place, but are water-deposited.

Of the igneous rocks eight types with several variants have been detected, representing rocks which range from soda-rhyolites to olivine-dolerites. Chemically, they embrace types containing silica-percentages as high as 80 and probably as low as 46.

In the more acid members of the series the percentage of total alkalies ranges as high as 8·82, but soda is always in excess of potash. The soda-rhyolites, soda-trachytes, and the two new types skomerites and marloesites belong to a soda-rich series, and present affinities with the alkaline rocks of Pantelleria. The mugearites, basalts, and dolerites belong to the subalkaline class, and may be compared with the plateau-basalts and basic sills of Tertiary age in the West of Scotland. Thus we have here a mixture

of alkaline and subalkaline types. Mineralogically, the more acid members of the series are peculiar in the abundance of soda-rich plagioclase felspars, and in the association of these minerals with porphyritic crystals of olivine, hypersthene, and augite. The lava-groups and the supposed sills thin out in an easterly direction from Skomer, where the greatest thickness is displayed, a feature which suggests a vent, or series of vents, lying to the west of that island.

In order of extrusion, except where the series is thinning, there appears to be a sequence from acid to basic and basic to acid. Thus there is a frequent repetition of the same type of rock, but seldom any extreme change in the characters and composition of contiguous flows.

In conclusion, I wish to take this opportunity of tendering my grateful acknowledgments to Mr. F. T. Howard and Mr. E. W. Small for most liberally placing at my disposal all their microscope-slides and much useful information which they had collected; to Mr. J. J. Neale, J.P., of Cardiff, the lessee of Skomer, for the many kindnesses which he showed me during my residence on the island; and to the Elder Brethren of Trinity House and Captain Mayar for allowing me to proceed to the Smalls Rocks on board the S.S. *Siren*. I am also much indebted to Major E. Howell and Mr. T. Picton, who accompanied me to Skomer; and to Prof. O. T. Jones, who worked with me over the difficult sections of the Wooltack peninsula.

EXPLANATION OF PLATE XI.

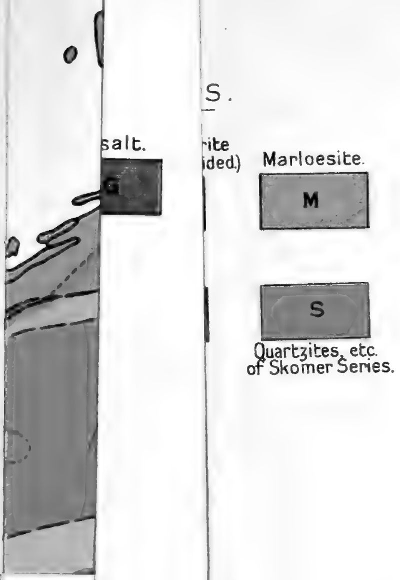
Geological map of Skomer Island and the adjacent Pembrokeshire coast, on the scale of 6 inches to the mile=1 : 10,560.

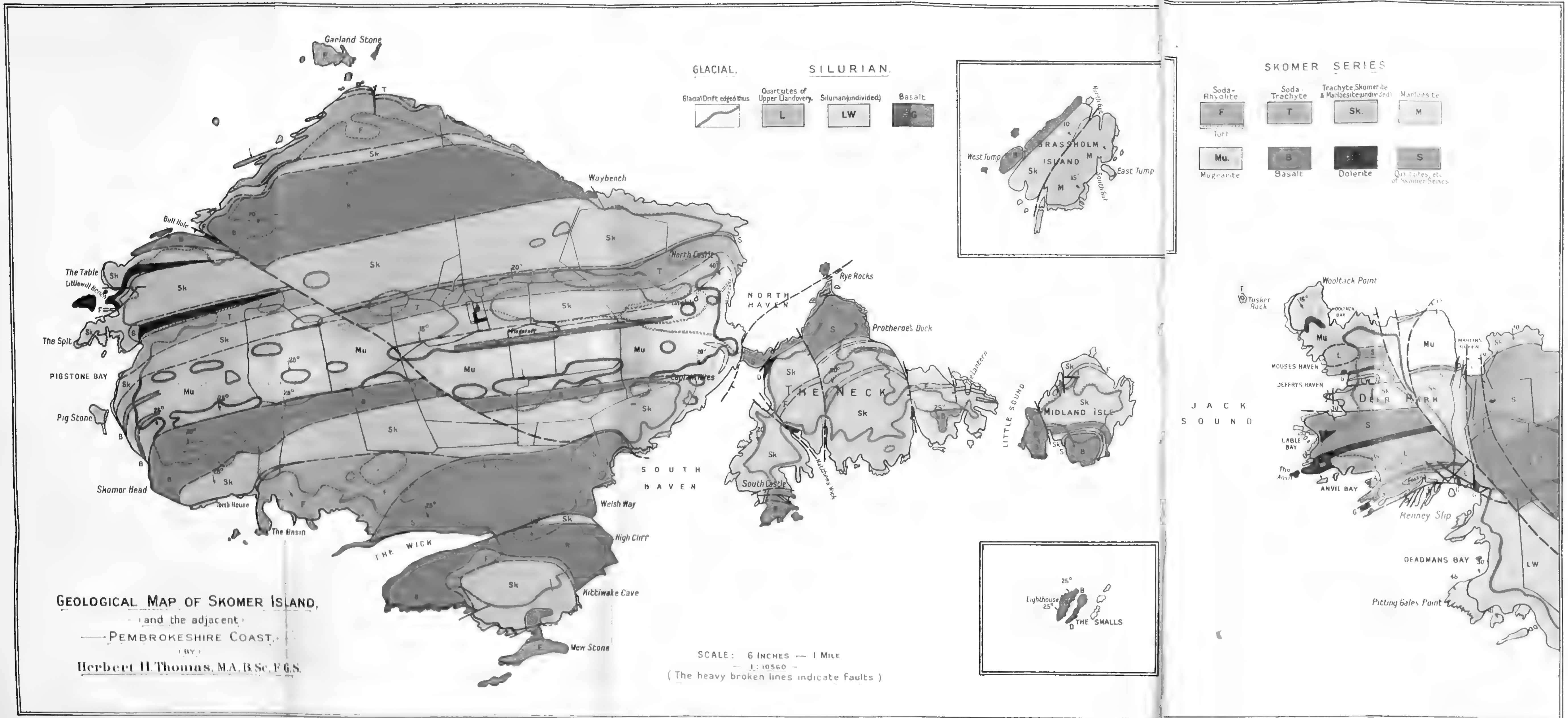
Discussion.

Mr. J. F. N. Green welcomed this paper as explaining a difficulty. On Ramsey Island, north of Skomer, certain rocks had been mapped, and repeatedly described as pre-Cambrian and basal Cambrian. It was now clear that these were simply the Skomer Series, the 'conglomerate' (of which the speaker showed specimens) being a nodular rhyolite. This discovery greatly simplified the geology of Ramsey, and enabled the speaker to confirm the Author's views as to the age of the Skomer rocks—since in Ramsey Island they rested, with apparent conformity, on shales belonging to the zone of *Didymograptus bifidus*.

Dr. J. S. Flett remarked on the interest of the paper as confirming the work of previous investigators, and describing types of igneous rocks not hitherto recognized.

In his work on the Lower Silurian volcanic rocks of the Southern Uplands of Scotland, Dr. Teall had shown that a series of diabases, diabase-porphyrites, pillow-lavas (rich in soda-felspar), keratophyres, and soda-felsites occurred—an association very similar to that described by the Author from Skomer, and belonging in


S.
salt.
G
rite
ided.)
Marloesite.
M
S
Quartzites, etc.
of Skomer Series.



GEOLOGICAL MAP OF SKOMER ISLAND,
and the adjacent
PEMBROKESHIRE COAST,
BY
Herbert H. Thomas, M.A., B.Sc., F.G.S.

SCALE: 6 INCHES — 1 MILE
— 1: 10560 —
(The heavy broken lines indicate faults)

Bemrose & Sons Ltd Derby & London

all probability to the same epoch of volcanic activity. From Mevagissey, in the south of Cornwall, Dr. Teall had recognized diabases, pillow-lavas, keratophyres, and soda-felsites belonging to a series which also was Lower Silurian. The continuation of these rocks to the south-west had been investigated by Mr. J. B. Hill and the speaker on the northern boundary of the Lizard district; and there again was an assemblage of diabases, pillow-lavas, and 'soda-felsites,' the last-named being rather coarse-grained, but having a composition very similar to some of the Author's rocks. Hence, it seemed established that one characteristic of the eruptions of this period was the development from one magma of basic types of rock (diabases, etc.) along with acid and intermediate types that were especially rich in soda-felspar.

The rocks called marloesites and skomerites by the Author were of great importance, as examples of igneous rocks of rather basic composition in which the dominant felspars contained a high proportion of albite. Long-continued investigation of the older basic rocks of Britain had convinced the speaker that in a vast number of cases the only felspar which they contained was albite. In part, this mineral was no doubt primary, but in large measure it was of secondary origin. Albitization, or the replacement of other felspars, especially lime-felspars, by albite was a process that had gone on in Britain on a very large scale. In Cornwall and Devon, for example, by far the greater number of the 'diabases' had been completely albitized. It was by no means easy to lay down the principles on which it could be determined whether the soda-felspar in any one of these Palæozoic igneous rocks was primary or secondary. But the speaker had had an opportunity of examining the Author's slides of marloesite and skomerite, and he agreed that the alkali-felspars of these rocks were for the most part original; and, although albitization had taken place to some extent, especially in the phenocrysts, it had not essentially modified the characters of the rocks.

The recognition of mugearites in Skomer Island was a welcome addition to our knowledge of British petrography. First established by Mr. Harker, only seven years ago, to include a limited number of Tertiary rocks in the island of Skye, this group had proved to have a wide distribution in the Carboniferous volcanic areas of Scotland. Mr. Barrow had found them in East Lothian, Mr. Bailey and the speaker in Midlothian, and Mr. Tyrrell in the Glasgow district; now, for the first time, they had been discovered in Wales.

Mr. Evan Small was glad to find that the observations made some years ago by Mr. F. T. Howard and himself had been largely confirmed. The Author had, however, very greatly extended these observations, and he congratulated him. Referring to Mr. Green's remarks, as to a nodular lava on Ramsey Island being mistaken for a sedimentary conglomerate, he noted that a similar error had been made by earlier observers on Skomer: for, on the old Geological Survey map, the whole of the spherulitic rhyolite of Tom's House and the Basin in the south of the island was shown as sedimentary. The true character of this rock was, however, recognized so long

ago as 1881 by Frank Rutley, from specimens collected by Sir Andrew Ramsay. Though the question did not lie strictly within the scope of the present paper, he would like to ask the Author whether he had come to any definite conclusion as to the source of the foreign boulders of hornblende-biotite-granite found on Skomer.

Mr. R. F. Gwinnell asked whether it was not desirable to use the term 'lime-bostonite,' or even the more definite name of 'mænaite,' as introduced by Prof. W. C. Brögger, in place of the very vague term 'keratophyre,' for the rocks which the Author described as being identical with lime-bostonite.

The President (Prof. Watts) called attention to the presence of olivine in the dolerites and basalts of the Skomer area—an unusual feature, so far as his experience went, in rocks of this age. He did not recognize, in the slides exhibited by the Author, any great resemblance between the bedded volcanic rocks and those of the zone of *Didymograptus murchisoni* on the Welsh borders. This difference might, perhaps, be accounted for by the different age of the Skomer rocks.

The Author, in reply, thanked the speakers for their appreciative remarks. With regard to the granite-boulders mentioned by Mr. Small, he considered that they, in common with many on the mainland of Pembrokeshire, derived their origin from the South of Scotland; they were associated with other rocks of Scottish derivation. The term 'keratophyre' had been used by him for certain rocks, classed as such by Rosenbusch in his most recent work; but he recognized that it was an ill-defined rock-group, and far too elastic to be of much classificatory value. He had not used the rock-name 'lime-bostonite' for these rocks, as their structure was not bostonitic, and also it seemed unadvisable to use the name 'bostonite' for extrusive rocks.

6. *The* ZONAL CLASSIFICATION *of the* SALOPIAN ROCKS *of* CAUTLEY *and* RAVENSTONEDALE. By Miss G. R. WATNEY and Miss E. G. WELCH. (Communicated by Dr. J. E. MARR, F.R.S., V.P.G.S. Read January 11th, 1911.)

[PLATE XII—GEOLOGICAL MAP.]

CONTENTS.

I. INTRODUCTION AND LITERATURE.

WE were induced by Dr. Marr to undertake the examination of the Salopian rocks of the area under consideration. He had failed in former years to obtain any zonal succession of the rocks of Wenlock age in the Lake District, owing to the cleaved nature of the rocks of that age above the lowest beds containing *Cyrtograptus murchisoni*. An examination of the less cleaved representatives of the Wenlock Beds near Cautley had convinced him that a succession might be established there, similar to that described in Scania by Tullberg, and in Wales and the Welsh borderland by Mrs. Shakespear and Miss Elles.

Our study of the Wenlock and Ludlow rocks of the Cautley and Ravenstonedale area has convinced us that these beds are capable of a division into zones, although some of the zones recognized farther south apparently do not persist when traced northwards to this district.

The Cautley and Ravenstonedale area is situated north of Sedbergh; its northern and eastern limits are defined by Carboniferous rocks, but on the west it is continuous with the Salopian of the Lake District.

The physiography of the district and the features due to ice-action have recently been described by Dr. Marr & Mr. Fearnsides[1]: it will suffice, therefore, to mention here that the area is a very hilly one, the fells often rising steeply from the 600- to the 1750-foot contour-line. North-west of the Rawthey the hilltops are everywhere formed of hard grits of Ludlow age, while on the south-east intrusive igneous rocks occupy the highest ground.

---

[1] Q. J. G. S. vol. lxv (1909) pp. 587 *et seqq.*

The general structure of the district at the present day is complex. Originally, there was probably simple folding which was subsequently affected by faulting. Most of the Cautley area is occupied by the Wandale-Hill syncline with a north-by-east and south-by-west axis, and the Bluecaster syncline having a north-north-east and south-south-west axis; these are separated by the Murthwaite-Park anticline, which passes into the Sally-Beck fault close to Narthwaite.

In both cases half only of the syncline remains. The Sally-Beck fault has cut out the north-western limb of the Bluecaster syncline, and the western part of the Wandale-Hill syncline has been faulted out by the Wandale-Hill fault, which has thrown down the Upper Wenlock and Ludlow Beds against the Stockdale and Coniston Limestone Series.

Numerous other small faults intersect the area, which are easily traced by zonal mapping.

Though exposures are well seen in many streams, yet no section shows the complete succession through the Salopian. Throughout the area the Wenlock and Ludlow strata differ markedly in their lithological characters: the former may be described as banded argillaceous flags, while the Ludlow rocks are tough, micaceous, sandy flags interstratified with unfossiliferous bands of grit.

Literature.

The Salopian rocks of this district have been briefly described in 'The Geology of the Country around Kendal, Sedbergh, Bowness, & Tebay' Mem. Geol. Surv. 1888, in which a classification into two groups is made: (1) Coniston Flags, and (2) Coniston Grits.

'The Geology of the Country around Mallerstang,' Mem. Geol. Surv. 1891, deals more particularly with the Cautley and Howgill area. The conformable relation of the Coniston Flags and the Stockdale Shales and the lithological characters of the beds are described. *Monograptus priodon* and *M. colonus* are recorded from the Coniston Flags, and *M. colonus* from the Coniston Grits. Unidentified graptolites are said to occur in the Bannisdale Slates.

The most important paper from our point of view is by Dr. Marr,[1] on the Wenlock and Ludlow strata of the Lake District, in which he divides the rocks into the following zones:—

LOWER LUDLOW.	Bannisdale Slates.	Zone of *Monograptus leintwardinensis.*
	Coniston Grits.	Zone of *Monograptus bohemicus.*
	Upper Coldwell Beds.	
	Middle Coldwell Beds.	Zone of *Phacops obtusicaudatus.*
WENLOCK.	Lower Coldwell Beds.	Zone of *Monograptus nilssoni (?).* Zone of *? Cyrtograptus carruthersi.*
	Brathay Flags.	Zone of *Cyrtograptus murchisoni.*

---

[1] Geol. Mag. dec. 3, vol. ix (1892) p. 534.

We have recognized the following zones in the Salopian rocks of Cautley and Ravenstonedale:—

LOWER LUDLOW.
- D_2 Zone of *Monograptus leintwardinensis* Hopk.
- D_1 Zone of *Monograptus nilssoni* Barr.

Phacops-obtusicaudatus Bed.

WENLOCK ......
- C_4 Zone of *Cyrtograptus lundgreni* Tullb.
- C_3 Zone of *Cyrtograptus rigidus* Tullb.
- C_2 Zone of *Monograptus riccartonensis* Lapw.
- C_1 Zone of *Cyrtograptus murchisoni* Carr.

II. THE WENLOCK BEDS.

The Wenlock Series is well exposed in three distinct areas in the Cautley district: namely, in the neighbourhood of the Rawthey, Wandale Hill, and Harter Fell. The rocks present three fairly distinct lithological types: (1) blue flags, (2) yellow sandy beds, and (3) red flags and grits; but in each case the same zones occur. The whole thickness of the Wenlock Series exposed in this area does not exceed 900 feet.

It has been possible to work out the approximate thickness of the zones in the Rawthey area as follows:

	Thickness in feet.
Zone of *Cyrtograptus lundgreni*	300 to 400
Zone of *Cyrtograptus rigidus*	178
Zone of *Monograptus riccartonensis*	160
Zone of *Cyrtograptus murchisoni*	100

(*a*) The Rawthey and the Western Slope of Bluecaster.

We have obtained our most complete sections through the Wenlock Series in the neighbourhood of the Rawthey. We therefore propose to describe the Wenlock Beds of this area in detail, and to give only general descriptions of the confirmatory sections elsewhere. Near the Rawthey each zone is exposed, and a conformable succession is obtained downwards into the Browgill Beds, and upwards into the *Phacops-obtusicaudatus* Bed, which here, as elsewhere in the Lake District, separates the strata of Wenlock from those of Ludlow age.[1]

The Wenlock Series occupies a narrow strip of country, from Birks Field Beck north-eastwards to the mouth of Wandale Beck. There is uniformity in the character of the beds throughout this area. They are massive jointed flags, finely banded, blue-grey when unweathered, and becoming brown on exposure to weathering agencies.

As has been noticed elsewhere,[2] the argillaceous character of the rocks has so greatly favoured cleavage that it is always difficult to obtain a good surface along the bedding-planes; even when such

---

[1] J. E. Marr, Geol. Mag. dec. 3, vol. ix (1892) p. 540.

[2] 'Geology of the Country around Mallerstang' (Expl. of Quarter Sheet 97 N.W.) Mem. Geol. Surv. 1891, p. 34.

a surface is obtained, the fossils in places are almost unrecognizable. The complicated system of faulting shows that movements have considerably affected the area; the presence of felsite and lamprophyre dykes is also of interest.

We have observed that the lowest Wenlock Beds invariably have their fossils preserved in relief, and this is a distinctive feature of these beds throughout the whole of the Cautley area.

An ascending section shows a greater tendency towards flagginess in the rock, and the introduction of pyrite in the form of abundant tiny cubes causes the strata to weather to an ochreous colour. The highest beds are characterized by irregular calcareous concretions, varying from a few inches to a foot in diameter; the banding is very marked, and the rocks weather to a light brown.

On the north and west the Sally Beck and other faults bring the Wenlock Beds against strata of their own age, or against the Browgill and Ludlow; but on the Bluecaster side there is a conformable passage downwards into the Browgill Group. The general dip of the beds is 30° north-north-westwards: they strike, therefore, across the gills which run in a north-westerly and westerly direction; but, although sections are numerous, they are, with the exceptions of those in Middle and Near Gills, never complete. As a rule, the fossils occur in bands in the rock, or even along definite bedding-planes. There seems to be no means, however, of distinguishing between the fossiliferous and the unfossiliferous bands.

It is from a study of the exposures in the Bluecaster gills and their fauna that we have become convinced that the Wenlock Beds of this area are divisible into four zones, namely:—

(1) Zone of *Cyrtograptus lundgreni*. C_4.
(2) Zone of *Cyrtograptus rigidus*. C_3.
(3) Zone of *Monograptus riccartonensis*. C_2.
(4) Zone of *Cyrtograptus murchisoni*. C_1.

Bluecaster Gills: (i) Far Gill.

The exposures in Far Gill are large and fairly fossiliferous; but the rocks are so highly cleaved that the fossils are almost obliterated, or seen only as smudged impressions. The highly cleaved state of the rocks may be due to the proximity of a fault on the north of the gill.

Cyrtograptus-murchisoni Zone (C_1).—Just above the old road splintered blue flags crop out in the gill-bed, dipping at 36° north-west by north. The fossils found were typical of the zone: *Cyrtograptus murchisoni*, *Monograptus priodon*, and *Orthoceras* occur in abundance. Below the old road two felsite-dykes cross the gill; the rocks are baked by these, and for a distance of 100 yards no fossil is to be found. These beds presumably belong to the zone of *Monograptus riccartonensis*.

The rocks in the higher part of the gill break with greater ease along the bedding-planes, and are ochre-stained.

Cyrtograptus-rigidus Zone (C_3).—At the bend of the stream the lithological character of the rock changes once more to blue-grey banded flags, much affected by cleavage. Along one bedding-plane *Monograptus flexilis* is abundant, and it is the only fossil that is easily recognizable. As we have found throughout the Cautley area that *M. flexilis* is common only in the *C.-rigidus* Zone, it may be taken as an index of that zone.

A characteristic feature of this zone is the introduction of secondary calcite along the joints and bedding-planes of the rock.

Cyrtograptus-lundgreni Zone (C_4).—100 yards down stream the beds dip 20° north of north-west at 24°, and maintain their dark coloration and cleaved character. They yield many specimens of *Monograptus vomerinus*. Some 30 yards from the upper field-wall, however, the beds change; they become tougher, and weather to a light brown. *M. flemingii* var. δ and *M. dubius* were found here. The presence of the former fossil and lithological change in the rocks indicate the *C.-lundgreni* Zone.

(ii) Middle Gill.

Cyrtograptus-murchisoni Zone (C_1).—The felsite-dyke of the old road has baked the *Murchisoni* Beds of Middle Gill; but just below the road a small exposure yields good specimens of *C. murchisoni, Monograptus priodon, M. vomerinus*, and *Retiolites geinitzianus.*

The zone extends down the gill for a distance of about 60 yards, and other small exposures indicate that *Cardiola* and *Retiolites geinitzianus* are abundant in the higher parts of the zone.

Monograptus-riccartonensis Zone (C_2).—The passage into this zone is marked by a complete change in the fauna. The name-fossil becomes very abundant; indeed, slabs of rock are often covered by it, to the exclusion of any other. The fossils are, on the whole, badly preserved, as the result of cleavage. A list of the forms found is enumerated in Table I (p. 222). The beds dip at 35° north-westwards.

Cyrtograptus-rigidus Zone (C_3).—This zone is well exposed on the right bank of the gill, and extends down stream for 60 yards below the little waterfall.

The rocks dip at 34° north-north-westwards; they are highly cleaved, and contain abundant cubes of pyrite, which cause them to weather to a bright orange colour. The higher part of the zone is characterized by the blackness of the fresh rock, and by the abundant development of secondary calcite. *Monograptus flexilis* is crowded along definite bands in association with *C. rigidus, M. vomerinus, M. hisingeri, M. dubius*, and *M. flemingii* var. δ; this last fossil becomes more abundant in the highest part of the zone.

Cyrtograptus-lundgreni Zone (C_4).—The lower part of Middle Gill is largely covered by drift, and the few exposures are poor. They yield *M. flemingii* var. δ and *M. dubius*, and dip at 41° north-north-westwards.

A large quarry between Middle and Near Gills on the Sedbergh road yields the associates *C. lundgreni*, *M. flemingii* var. δ, and *M. dubius*. The rock is a very massive blue flag.

(iii) Near Gill.

In Near Gill the exposures are smaller than in either of the gills already described, but the fossils are in a better state of preservation, and all four zones are well seen.

Cyrtograptus-murchisoni Zone (C_1).—Some 30 yards below the old road, a small exposure on the left bank of the gill yields *C. murchisoni* and the forms associated with that fossil. The beds are much affected by the 'old road dyke,' and have been converted into pale, flinty, unbedded rock.

Monograptus-riccartonensis Zone (C_2).—For the next 100 yards the only exposures are very small ones in the gill-bed. It is difficult to identify the fossils, but, from their crowded occurrence and general form, they can be recognized as *M. riccartonensis*.

Cyrtograptus-rigidus Zone (C_3).—At the bend of the stream ochre-stained beds form a small cliff on the right bank, and a scree-slope on the left bank; their dip is 32° north-westwards.

A richly fossiliferous band occurs in the cliff, containing many examples of *C. rigidus* and *Monograptus flexilis*; on the opposite bank *C. linnarssoni*, *C. rigidus*, and *M. flexilis* occur abundantly. *Retiolites spinosus* is also common—this fossil has hitherto been recorded in Britain from the Lower Ludlow rocks only. About 25 yards lower down, an exposure in the left bank yields *C. rigidus* and *Monograptus flemingii* var. *a*.

The higher part of this zone occupies two scree-slopes 100 yards down stream; here the rocks are characteristically pyritous, and contain *M. flemingii* var. *a* in abundance.

A small lamprophyre-dyke occurs in the left bank of the gill just below the screes: its trend is north-west by west.

Cyrtograptus-lundgreni Zone (C_4).—Below the dyke pyrite is no longer seen in the rock, which assumes the normal cleaved appearance. The most common species is *M. flemingii* var γ, here, as usual, characteristic of the lower part of the zone. Some yards farther down *C. lundgreni* occurs in the left bank. Down stream the rocks become less massive, and show a greater tendency to break along the bedding-planes.

The beds throughout the zone dip at 26° north-westwards. Near the Sedbergh road they become lighter in colour and more sandy.

M. flemingii var. γ, *C. lundgreni*, and *M. dubius* are all contained in these highest beds.

Apart from the three gills mentioned previously, numerous small streams which run from Bluecaster into the Rawthey are, with a few exceptions, nameless. We have, therefore, for the sake of convenience, named them alphabetically (see map, Pl. XII).

One or more of the Wenlock zones crop out in each of these gills, and, as the results of our work in them are summarized in Table II (p. 222), it is only necessary here to mention a few points of interest.

(iv) West Gill.

This gill, which flows into the Rawthey below Low Haygarth, is of importance, not only because three of the zones are exposed in its banks, but on account of the conformable succession into the Browgill Beds which can be traced in the southern branch of the gill. *Cyrtograptus murchisoni* occurs in the bed of the gill 20 yards below a cowshed; at the same distance above the shed the Browgill Beds crop out.

The *Riccartonensis* Zone (C_2) comes on 6 yards below *C. murchisoni.* Its beds are almost black, veined with calcite, and speckled with cubes of pyrite; their dip is 5° west of north-west at 55°. The lower part of West Gill is largely occupied by two felsite-dykes, the lower of which is continuous with the 'old road dyke' of Near, Middle, and Far Gills.

Exactly 52 yards from the Sedbergh road, and just below a small lamprophyre-dyke, the rocks dip at 21° north by west, and yield the fauna of the *C.-lundgreni* Zone (C_4).

The only other exposures that show the succession from the Browgill into the Wenlock Beds occur—

(1) In a small dry valley running westwards in continuation of the head of Gill H; and

(2) 20 yards below Ecker Secker Bridge.

Both these sections show the marked lithological and faunal changes which take place between the beds.

In Ecker Secker Beck the *Cyrtograptus-murchisoni* and *Monograptus-riccartonensis* Zones occur, but the *Cyrtograptus-rigidus* Zone seems to be cut out by faulting. At the hedge on the right bank of the beck there is evidence of faulting; the dip of the beds changes suddenly from 35° to 75° north-north-westwards, and there is considerable local development of secondary calcite in ramifying threads and veins. Some yards lower down the rock becomes concretionary, and *Monograptus flemingii* var. δ occurs. The presence of another fault at the mouth of the beck is proved by a fault-breccia seen in the left bank, accompanied by large veins and bands of calcite.

Table I.—Graptolites from Far, Middle, and Near Gills.

Species and Varieties. C = very common. c = common. R = very rare. r = rare.	Zone of *Cyrtograptus murchisoni*. C_1.			Zone of *Monograptus riccartonensis* C_2.			Zone of *Cyrtograptus rigidus*. C_3.			Zone of *Cyrtograptus lundgreni*. C_4.		
	Far.	Middle.	Near.	Far.	Middle.	Near.	Far.	Middle.	Near.	Far.	Middle.	Near.
Cyrtograptus carruthersi Lapw.	...	...	...	...	...	...	...	...	...	...	...	c
Cyrtograptus lundgreni Tullb.	...	...	...	...	...	...	...	...	...	...	...	C
Cyrtograptus linnarssoni Lapw.	...	...	...	...	...	...	...	...	C	...	...	...
Cyrtograptus murchisoni Carr.	c	C	C	...	...	...	...	...	...	...	...	...
Cyrtograptus murchisoni, var. *crassiusculus* Tullb.	...	...	r	...	...	...	...	...	...	...	...	...
Cyrtograptus rigidus Tullb.	...	...	...	...	...	...	...	C	C	...	...	...
Monograptus flemingii Salt. var. *α* Elles	...	...	...	...	...	...	...	...	C	...	...	...
" " " " *β* "	...	...	...	...	...	...	?	C	C	...	...	...
" " " " *γ* "	...	...	...	...	...	...	...	...	...	...	c	C
" " " " *δ* "	...	...	...	...	...	...	...	R	...	C	C	C
Monograptus flexilis Elles	...	...	...	...	R	...	C	C	C	...	...	...
Monograptus capillaceus Tullb.	...	...	...	...	...	r	...	...	r	...	...	...
Monograptus dubius Suess	...	...	...	...	C	C	...	C	C	C	C	C
Monograptus priodon Bronn	C	C	C	...	...	...	...	...	...	...	...	...
Monograptus riccartonensis Lapw.	...	...	...	...	C	C	...	...	...	...	...	...
Monograptus hisingeri Carr. var.	...	...	...	...	C	C	c	c	C	...	...	...
Monograptus vomerinus Nich. var. *α* Elles	...	C	C	...	C	C	C	C	C	...	...	C
" " " " *β* "	...	c	c	...	r	...	C	C	c	...	...	...
Retiolites geinitzianus Barr.	C	C	C	...	...	...	...	...	...	...	...	...
Retiolites spinosus Wood	...	...	...	...	...	c	...	...	C	...	..	...

Table II.—Graptolites from Bluecaster Gills.

Species and Varieties. C = very common. c = common. R = very rare. r = rare.	Zone of *Cyrtograptus murchisoni*. C_1.		Zone of *Monograptus riccartonensis*. C_2.		Zone of *Cyrtograptus rigidus*. C_3.					Zone of *Cyrtograptus lundgreni*. C_4.	
	Gill G.	Ecker Secker.	Gill G.	Ecker Secker.	Gill A.	Gill B.	Gill E.	Gill F.	Gill G.	Gill E.	Ecker Secker.
Cyrtograptus linnarssoni Lapw.	...	...	...	...	...	...	...	C	...	...	...
Cyrtograptus murchisoni Carr.	C	c	...	...	...	...	...	...	...	...	...
Cyrtograptus murchisoni, var. *crassiusculus* Tullb.	C	...	...	...	...	...	...	...	...	...	...
Cyrtograptus rigidus Tullb.	...	...	...	...	C	C	...	C	C	...	...
Monograptus flemingii Salt. var. *α* Elles	...	...	...	...	C	C	c	C	...	...	...
" " " " *β* "	...	...	...	...	...	...	c	c	...	...	...
" " " " *δ* "	...	...	...	...	R	...	...	...	...	C	C
Monograptus flexilis Elles	...	...	...	...	...	...	...	C	C	...	...
Monograptus dubius Suess	...	...	C	C	C	C	...	C	C	...	...
Monograptus priodon Bronn	C	C	...	...	...	...	...	...	...	...	...
Monograptus riccartonensis Lapw.	...	...	C	C	...	...	...	...	...	...	...
Monograptus hisingeri Carr. var.	...	...	...	c	C	...	...	c	c	...	...
Monograptus vomerinus Nich. var. *α* Elles	...	...	c	...	...	...	...	...	...	...	...
" " " " *β* "	...	...	...	...	...	...	...	r	c	...	...
Retiolites geinitzianus Barr.	C	C	...	...	...	...	...	...	...	...	...

The River Rawthey.

The part of the Rawthey under consideration lies between the mouth of Wandale Beck and Cock's Dub. The Wenlock zones exposed on the western slope of Bluecaster should in turn appear in the banks of the Rawthey; but, as the result of faulting, the succession of zones is irregular.

Above Handley's Bridge the three lowest zones strike across the Rawthey in a south-easterly direction, but they are cut off at the bridge by a fault trending north-west and south-east.

Both the *Cyrtograptus-murchisoni* (C_1) and *Monograptus-riccartonensis* Zones (C_2) near the mouth of Wandale Beck have yielded the characteristic graptolites enumerated in Table I (p. 222).

The zone of *Cyrtograptus rigidus* (C_3) which conformably succeeds them down stream yields few fossil remains; and those which do occur, *Monograptus flexilis* and *M. flemingii* var. *a*, are poorly preserved, owing to movement in the rock close to Handley's Bridge, where there is evidence of both folding and faulting on a considerable scale. At Handley's Bridge the beds change their dips from south-south-west to west by north, and they are seen to strike across the river, and then to bend round towards the right bank.

Although exposures are good below Handley's Bridge, there is a scarcity of palæontological evidence; two zones only are found. The *Cyrtograptus-lundgreni* Zone (C_4) extends from Handley's Bridge to Cautley Thwaite, with the exception of some yards below the mouth of Backside Beck, and is conformably succeeded by the zone of *C. rigidus* (C_3). Below the fault at Low Wardses the *C.-lundgreni* Zone (C_4) again appears.

The general dip of the rocks throughout is in a north-north-westerly direction, although variations occur in different parts of the river where it is crossed by faults, as, for example, at the mouth of Backside Beck, where the dip changes to south-west by south, and above High Wardses Bridge, where it is 50° east of north.

The evidence for the establishment of the succession lies below the mouth of Backside Beck. The beds dipping 22° west-north-westwards are yellowish and sandy when fresh, and yield *Phacops obtusicaudatus* in abundance. It will be shown elsewhere that beds containing that trilobite are immediately overlain by the lowest Ludlow, Zone of *Monograptus nilssoni* (D_1); hence in this part we have the completion of the Wenlock succession.

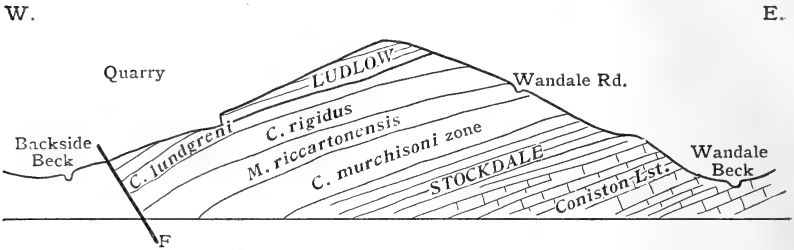
The four Wenlock zones are exposed in the Bluecaster Gills, and are conformably overlain by the *Phacops-obtusicaudatus* Bed as seen in the Rawthey.

(*b*) Wandale Hill.

The Wenlock and Ludlow rocks form the greater part of the top and the eastern slope of Wandale Hill. These beds are limited on the west by the Wandale-Hill fault, which runs in a north-north-

easterly and south-south-westerly direction, and brings them abruptly against the Stockdale Shales and the Coniston Limestone Series. On the south the Sally-Beck fault forms the boundary of the Wenlock Beds: this runs close to, and almost parallel with, the Rawthey.

Fig. 1.—*Section through Wandale Hill.*



[Horizontal scale: 6 inches = 1 mile.]

The eastern slope of the hill shows a conformable passage downwards from the Wenlock into the Stockdale Shales and the Coniston Limestone Series. All these beds sweep round from a north-easterly to an easterly direction below Adamthwaite, and join the rocks exposed in Harter Fell.

Adamthwaite Sike, which forms the northern limit of Wandale Hill, runs through drift, and it is therefore impossible to determine the trend of the beds near the northern limit of the Wandale-Hill fault.

The Ludlow rocks occur as an oval outcrop capping Wandale Hill, and a section showing the Ludlow resting upon the highest Wenlock Beds is seen on the west side of the hill; but on the east side, in the gills near Wandale Farm (which we have named W_1 and W_2) only the three lowest Wenlock zones are exposed. The Wenlock strata of this area are yellow, banded, sandy flags, passing up into the blue banded flags typical of the Rawthey area.

Cyrtograptus-murchisoni Zone (C_1). — The boundary between the Browgill and the Wenlock Beds occurs 40 yards below the Fell wall on East Wandale.

The lowest Wenlock Beds strike parallel to, and are well exposed in many small sections along, the Wandale road. The conformable relation of these *C.-murchisoni* Beds to the Browgill Beds below is well seen in three small gills north of the Narthwaite larch wood and in the numerous gills near Wandale. Their passage upwards into the *Monograptus-riccartonensis* and *Cyrtograptus-rigidus* Zones is best shown in two small gills north of Wandale Farm.

In one of these, W_1, the base of the *Cyrtograptus-murchisoni* Zone is exposed 20 yards below the road, and its upper limit occurs at the road. The rocks, dipping at an angle of 40° north-west by west, are massive, banded, grey and yellow, sandy flags. The

fossils, as elsewhere in this zone, are preserved in relief. Table III (p. 226) shows that the characteristic faunal assemblage of the *Murchisoni* Zone occurs here, *Cyrtograptus murchisoni* and *Retiolites geinitzianus* being especially abundant. *Orthoceras primævum* is also of common occurrence.

Farther north is Gill W_2, in which good exposures of this zone again occur. The zone has been traced to a distance of 30 yards above and 25 yards below the road. The rocks here are roughly cleaved, and dip at an angle of 32° north-north-westwards.

onograptus-riccartonensis Zone (C_2).—Good exposures of this zone are found in Gills W_1 & W_2, and isolated exposures yielding the type-fossil occur farther north in the hillside.

South of Gill W_1 no exposures of this zone are found, but the outcrop of beds evidently narrows towards the Sally-Beck fault, as is indicated by the close proximity of the *Murchisoni* and the *Lundgreni* Zones in the larch-wood.

In Gill W_1 the transition between the *Murchisoni* and the *Riccartonensis* Zones is abrupt, and marked by both a lithological and a palæontological change. On the lower side of the Wandale road the grey banded rocks containing the *Murchisoni* fauna occur; while on the upper side these are replaced by pale-yellow sandy rocks, in which the bedding-planes are crowded with *Monograptus riccartonensis*. The zone extends 48 yards up the gill, the rocks dipping at an angle of 17° north-west by west.

Gill W_2 also gives a good section through the *Riccartonensis* Zone, but only the lower part yields many fossils. The rocks dip at 31° north-westwards, and retain their sandy character; they pass, however, occasionally into a darker and more banded type, as in the hillside exposures towards Adamthwaite, and in Wandale Beck 300 yards below Adamthwaite.

Cyrtograptus-rigidus Zone (C_3).—This zone is well exposed in Gills W_1 and W_2, and in an old quarry-road towards Adamthwaite. Southwards also it has been possible to trace the zone in a small exposure in Wandale slope.

The lower part has the same yellow sandy character as the *Monograptus-riccartonensis* Zone; but, when traced upwards, it gradually passes into a tough, blue, banded rock, which weathers brown.

Characteristic fossils are abundant. In Gill W_1 the beds dip at 42° west-north-westwards, and extend to the top of the gill; but numerous loose blocks on the hillside above, containing fossils common to the zone, indicate that only the lower part is exposed in the gill.

Gill W_2 extends higher up the hillside, and it has therefore been possible to trace the upper parts of the *Cyrtograptus-rigidus* Zone here. The transition between the *C.-lundgreni* and the *C.-rigidus* Zones is, however, hidden.

Cyrtograptus-lundgreni Zone (C_4).—This zone is best exposed in a small stream-section occurring in a larch-wood above Handley's Bridge. The rocks dip at 25° west by south, and are massive, blue, banded flags containing the characteristic zonal graptolites.

There are no other exposures of this zone on the eastern slope of Wandale Hill, but the fossils may be picked up in abundance at the gathering-grounds of the gills.

A massive grey-green grit occurs near the top of Wandale Hill: it is unfossiliferous, and probably forms part of the Lower Ludlow Series, since nowhere in the area does a grit appear in the Upper Wenlock.

Table III.—Wandale-Hill Wenlock Graptolites (Gills W_1 & W_2).

Species and Varieties. C = very common. c = common. r = rare.	Zone of *Cyrtograptus murchisoni.* C_1		Zone of *Monograptus riccartonensis.* C_2		Zone of *Cyrtograptus rigidus.* C_3		Zone of *Cyrtograptus lundgreni.* C_4	
	W_1.	W_2.	W_1.	W_2.	W_1.	W_2.	W_1.	W_2.
Cyrtograptus linnarssoni Lapw.	...	...	...	...	...	c	...	...
Cyrtograptus murchisoni Carr.	C	C	...	...	...	...	...	...
Cyrtograptus rigidus Tullb.	...	...	...	...	c	c	...	...
Monograptus capillaceus Tullb.	...	...	r	r	...	...	...	...
Monograptus dubius Suess	...	...	...	...	...	C	...	...
Monograptus flemingii Salt. var. δ Elles.	...	...	...	...	...	...	C	C
" " " " β "	...	...	...	...	...	...	...	c
" " " " α "	...	...	...	...	...	C	...	...
Monograptus flexilis Elles	...	...	...	...	c	C	...	...
Monograptus hisingeri Carr. var.	C	...	C	...	C	...	...	...
Monograptus priodon Bronn	C	C	...	...	...	...	...	...
Monograptus riccartonensis Lapw.	...	...	C	C	...	...	...	...
Monograptus vomerinus Nich. var. α Elles	C	C	...	C	...	...	...	...
" " " " β "	...	...	...	...	c	...	...	...
Retiolites geinitzianus Barr.	C	C	...	...	...	...	...	...
Retiolites spinosus Wood	...	...	...	...	C	C	...	...

West Wandale.

On the west side of Wandale Hill the Wenlock again crops out, and the *Lundgreni* Zone (C_4) is found overlain by the *Monograptus-nilssoni* Zone (D_1) of the Lower Ludlow. The Lower Wenlock zones are cut out by the Wandale-Hill fault, which has let down the Upper Wenlock and Ludlow Beds against the Browgill Beds and the Coniston Limestone Series.

The only exposures occur in a small gill, which flows down from the site of an old quarry above Narthwaite to join Backside Beck. Where the gill crosses the Mountain-View Road, the Coniston-Limestone Beds are faulted against the Wenlock strata. These appear as blue finely-banded flags, with many concretions. The dip

is at 59° south-west by south, and cleavage has been induced in the beds. *C. lundgreni* and *Monograptus flemingii* vars. γ & δ were found a few yards above the road. Yellow sandy beds yielding small brachiopods and *M. dubius* overlie the *C.-lundgreni* Zone (C_4), and above follow darker gritty beds containing graptolites of the *M.-nilssoni* Zone.

(*c*) Harter Fell.

The top of Harter Fell is occupied by Lower Ludlow rocks, and, on passing down its southern and south-eastern slopes, we traverse the Wenlock, Browgill, and Llandovery Beds in turn.

Numerous little gills, making deep gashes in the hillside, afford the best exposures of the Wenlock Beds. The fossils of the lowest Wenlock are preserved in the typical solid form, and the beds themselves are blue-grey banded flags. A lithological change comes in with the appearance of *Monograptus riccartonensis*; the rocks weather with a red stain, and are gritty. The red coloration becomes accentuated as the beds are traced upwards into the red Ludlow grits.

The Wenlock zones sweep round Harter Fell in a semicircle, and are cut off abruptly on the east by the Sally-Beck fault. They all crop out within the short distance of 230 yards. Their prevailing angle of dip is a high one, and the direction varies between north and north-north-west. The Browgill Beds are exposed below the Wenlock in Five Gills; elsewhere the strata are hidden by grass and drift.

Each individual zone differs little from those previously described. Therefore only a list of places is given, where each zone is exposed:—

C.-murchisoni Zone (C_1)	Gill 2 (Five Gills).
M.-riccartonensis Zone (C_2)	Gills. 2, 3, 4, 5 (Five Gills). Odd Gill, and at the waterfall in Wandale Beck below Adamthwaite.
C.-rigidus Zone (C_3)	Gills 3, 4, 5 (Five Gills).
C.-lundgreni Zone (C_4)	Gills 2, 3, 4, 5 (Five Gills). Gills 1 & 2 (Three Gills).

West of Harter Fell the Wenlock Beds are covered by drift, the only exposures being those mentioned in Odd Gill and Wandale Beck. They reappear, however, in Spen Gill. Here the Browgill Beds pass up conformably into blue banded flags containing *Monograptus priodon*, *Cyrtograptus murchisoni*, and *Retiolites geinitzianus*. Higher in the gill the rocks have suffered much from cleavage, and the only fossil fragments found were unrecognizable.

At the waterfall calcareous concretions appear, and with them *Monograptus flemingii* var. δ and *M. irfonensis*. *Phacops obtusicaudatus* was found in a yellow sandy bed occurring between the top of the *C.-lundgreni* Zone and the base of the *M.-nilssoni* Zone.

III. The Ludlow Beds.

The Lower Ludlow rocks occupy the greater part of the high ground of the Howgill Fells; the lower beds pass up conformably into the Bannisdale Slates, which in their turn pass beneath the Carboniferous rocks of Ravenstonedale. An outlier of Ludlow rock, which is not indicated on the Geological Survey map, occupies the summit of Wandale Hill.

The Ludlow rocks of the Howgill area consist largely of banded, micaceous, sandy beds alternating with grit-bands; these serve to distinguish the Ludlow rocks from the argillaceous flags of the Wenlock Series. Graptolites are fairly abundant in the lowest Ludlow Beds, but usually they are poorly preserved owing to the coarse nature of the rock; exceptions are found in those bands where the fossils occur in relief.

Dr. Marr[1] has shown that the Ludlow rocks of the Lake District may be divided into two main zones, those of *Monograptus bohemicus* at the base and *M. leintwardinensis* at the upper limit. Our work in this area supports this earlier classification.

In addition to the graptolite fauna, lamellibranchs and brachiopods occur in much greater abundance here than in the Wenlock Flags.

The Ludlow Beds are most fully developed in the Ravenstonedale Common area; but, since the watershed occurs in the Ludlow rocks, no complete section is found, and hence it has not been possible to trace the passage between the *Nilssoni* and the *Leintwardinensis* Zones. There is evidence of considerable folding on both sides of the watershed, and this is further complicated by two sets of fault-lines which run at right angles to one another, and the great shatter-belt described by Dr. Marr & Mr. Fearnsides.[2] Traced upwards from the yellow *Phacops-obtusicaudatus* Bed, the rocks may be divided into two groups:—

(1) Blue-grey banded flags alternating with unfossiliferous blue micaceous beds which are cleaved and silky in appearance, succeeded by red micaceous grits and flags, with few fossils.

Throughout this group fossils belonging to the *Monograptus-nilssoni* Zone are found.

(2) Grey banded flags, red grits, and blue slaty beds (the Bannisdale Slates) in which *M. leintwardinensis* is common.

The outcrop of the greater part of the *M.-leintwardinensis* Zone is not inserted in the accompanying map (Pl. XII), as it occurs farther north, and agrees practically with the line between the Coniston Grit and the Bannisdale Slate on the Geological Survey map. The most fossiliferous development of the lowest Ludlow occurs on Wandale Hill.

---

[1] Geol. Mag. dec. 3, vol. ix (1892) p. 541.

[2] Q. J. G. S. vol. lxv (1909) pp. 589 *et seqq.*

(*a*) The Ludlow Beds of Wandale Hill.

The summit and the north-western slope of Wandale Hill are formed of Lower Ludlow strata, the outcrop being semi-elliptical; on the east and south-west the lowest beds pass conformably downwards into the Wenlock Series. On the west, however, they are faulted against the Browgill Beds, and farther north along the Spengill Road are faulted out. Only the *Monograptus-nilssoni* Zone is found on Wandale Hill.

The exposures occur in an old quarry above Narthwaite, just below the Spengill Road; and in the heads of three gills which cross the same road farther north.

Narthwaite Quarry.—The lowest beds crop out immediately below the west side of the quarry-wall; they are tough, blue, banded flags, rather coarse and sandy in texture, yielding *Monograptus dubius* in association with *M. colonus*.

Above the wall fossils typical of the *M.-nilssoni* Zone are abundant. They occur in relief in a band of blue flags, above which sandy and minutely banded blue flags dipping at 36° south-west by south are exposed; the fossils in these are preserved as impressions only. *M. colonus*, *M. bohemicus*, and *Cardiola interrupta* are met with most frequently.

The higher beds in the quarry are grey-green, slaty, unfossiliferous flags.

TABLE IV.—WANDALE-HILL LUDLOW GRAPTOLITES.

Species and Varieties. C = very common. c = common. r = rare.	Zone of *Monograptus nilssoni*.			
	Narthwaite Quarry.	Gill 1.	Gill 2.	Gill 3.
Monograptus bohemicus Barr.	C	...	...	...
Monograptus chimæra Barr.	C	...	C	C
" " var. *salweyi* Hopk.	...	...	...	c
Monograptus colonus Barr.	C	C	C	C
Monograptus comis Wood	C	...	...	...
Monograptus dubius Suess	c	...	...	c
Monograptus nilssoni Barr.	r	...	r	...
Monograptus rœmeri Barr.	...	...	...	c
Monograptus varians var. *pumilus* Wood	C	...	...	c
Monograptus wandalensis, sp. nov.	C	...	...	...
Retiolites nassa Holm	...	...	c	...

Spengill Road Gills.—The Ludlow strata in these three gills are sandy, banded flags of a higher horizon than those exposed in Narthwaite Quarry; when weathered the rocks assume an

ochreous colour. The heads of all three gills rise in the *M.-nilssoni* Zone, as will be seen from an examination of Table IV (p. 229). Fossils are fewer than in the Narthwaite-Quarry beds; but in the third and largest gill they are well preserved and fairly abundant.

Two exposures of a fine grey-green grit—one in the site of an overgrown quarry near the summit of the hill overlooking Adamthwaite, and the other in the hillside above Narthwaite, probably represent a higher horizon of the *M.-nilssoni* Zone.

(*b*) The Ludlow Beds of Ravenstonedale Common.

The beds, dipping in a general north-north-easterly direction, are exposed in numerous streams flowing northwards and southwards from the watershed, and in small quarries occurring in the hillsides.

Spen Gill and Dale Gill.—The Lower Ludlow rocks are well exposed in the higher part of Spen Gill, which flows southwards from the Howgill watershed, and in Dale Gill flowing northwards.

At the source of Spen Gill good specimens of *Monograptus bohemicus* and *M. colonus* were obtained in some abundance, from a micaceous band of rock which weathered red; and throughout the upper part of the gill occasional fossiliferous bands are found in the blue banded grits, yielding *M. colonus* and *M. rœmeri*.

Across the watershed small scree-slopes occur in the hillside of Green Bell; palæontological evidence still points to the continuation of the *M.-nilssoni* Zone (D_1), for graptolites of the *colonus* type preserved in relief are common.

At the source of Dale Gill similar rock crops out; but the fossils are poor, and only preserved as impressions. The head of Stwarth Gill has yielded *Cardiola*, *Orthis*, and *Pterinæa*; and a few badly preserved graptolites occur in a red grit which alternates with red micaceous flags.

Lower down the gill the rocks again change to blue-grey grits, sandy beds with lamellibranchs and trilobites (*Acidaspis*), and smooth unfossiliferous flags. No graptolites were found until 50 yards below the junction of Stwarth and Dale Gills, where a highly fossiliferous blue band crops out at the bend of the river, containing *Monograptus leintwardinensis* with many lamellibranchs and trilobites. The beds dip at 36° east-north-eastwards.

Gais Gill and Adamthwaite Road.—A small quarry situated in Adamthwaite Bank, overlooking the right tributary of Gais Gill, has yielded abundant specimens of *Monograptus leintwardinensis*, which tend to be preserved in relief in a hard, banded, blue-grey flag. No further exposures occur until this tributary joins with Long Gill, forming Gais Gill. Here the rock dips at 37° north-north-eastwards; it consists of coarse and fine red grits alternating with flags in which *M. bohemicus*, *M. colonus*, and

Cardiola interrupta are common. These fossils all indicate the *M.-nilssoni* Zone.

The gill flows practically on the strike of these rocks as far as the footbridge on the Adamthwaite Road. A small exposure of typical hard, blue, banded Wenlock rock occurs here in the left bank of the stream, and has yielded specimens of *M. flemingii* var. *α*, which is a typical fossil of the *C.-rigidus* Zone. Beyond this point, for a distance of 170 yards, no good exposure occurs until a quarry on the Adamthwaite Road is reached, in which fossils characteristic of the *M.-nilssoni* Zone are fairly numerous. The rock is similar to that previously described in the upper part of Gais Gill, and dips at an angle of 20° north-north-eastwards. Beyond this quarry the surface is again hidden by vegetation, until exposed in a cutting in the roadside, opposite a shed south of Banks Farm, which again yielded *M. leintwardinensis*. The rocks dip 39° north-north-eastwards. This succession of zones, with the rocks all dipping in a general north-north-easterly direction, seems to point to isoclinal folding in this region.

Isolated exposures.—The zones of *Monograptus nilssoni* and *M. leintwardinensis* are seen in numerous other stream-sections, but only a few present fresh features of interest.

Stonely Gill and Two Gills rise in Harter Fell, and show large exposures of Lower Ludlow rocks, which only differ from those previously described in their red coloration. *M. bohemicus*, *M. colonus*, and *M. rœmeri* were found, in addition to *Cardiola interrupta* and *Orthoceras*; these fossils clearly indicate the zone of *M. nilssoni* (D_1). The *M.-leintwardinensis* Zone (D_2) was met with in Bowderdale Beck and in Pinskey Gill, just north of Pinskey Bottom: the latter locality yielded *M. leintwardinensis* and its variety *incipiens*; these two varieties have so far not been found together.

IV. CORRELATION.

(1) The Wenlock Beds.

A glance at Table V (p. 233) will serve to show that there is abundant evidence in the Cautley area for a zonal classification of the Wenlock Beds. Each of the four zones is clearly marked off from the other three by a distinctive fauna; also the fossils which give their names to the zones are strictly limited to one zone, and, with the exception of *Cyrtograptus lundgreni*, range through the entire zone.

We have preferred to retain *C. lundgreni* as the zone-fossil of the highest Wenlock Beds, as Miss Elles has already chosen it for beds of the same age in the Welsh Borderland. For purposes of identification of the zone, however, the varieties of *Monograptus flemingii* *γ* & *δ* have been most useful to us.

As *Cyrtograptus linnarssoni* is found only in association with *C. rigidus* at Cautley, we have correlated our *Rigidus* Zone with the zones of *C. linnarssoni* and *C. rigidus* of Builth.

The assemblage of forms below the *C.-rigidus* Zone do not justify the interpolation of another zone in Cautley between this and *Monograptus riccartonensis*. We have recognized four zones only (see Table V, p. 233).

TABLE V.—DISTRIBUTION OF THE GRAPTOLITES IN THE SALOPIAN ROCKS OF WALES AND THE WELSH BORDERLAND, AND IN THOSE OF CAUTLEY AND RAVENSTONEDALE.

Species and Varieties. C = very common. c = common. R = very rare. r = rare.	WALES and the WELSH BORDERLAND.					CAUTLEY and RAVENSTONEDALE	
	Ludlow.					Ludlow.	
	Zone of *Monograptus vulgaris.*	Zone of *Monograptus nilssoni.*	Zone of *Monograptus scanicus.*	Zone of *Monograptus tumescens.*	Zone of *Monograptus leintwardinensis.*	Zone of *Monograptus nilssoni.*	Zone of *Monograptus leintwardinensis.*
Monograptus bohemicus Barr.	...	C	c	r	...	C	...
Monograptus chimæra Barr.	...	c	C	r	...	C	...
,, ,, var. *α*	...	?	c	...	...	...	...
,, ,, var. *salweyi* Hopk.	...	c	...	...	...	C	...
Monograptus colonus Barr.	...	C	...	...	...	C	...
,, ,, var. *compactus* Wood	...	r	...	...	...	...	...
Monograptus comis Wood	...	r	...	...	...	c	...
Monograptus crinitus Wood	...	r	...	...	...	...	...
Monograptus dubius Suess	C	c	c	...	...	c	...
Monograptus gotlandicus Perner	...	r	...	...	...	...	...
Monograptus leintwardinensis Hopk.	...	...	...	...	c	...	C
,, ,, var. *incipiens* Wood	...	...	...	...	c	...	c
Monograptus nilssoni Barr.	...	C	...	...	...	R	...
Monograptus rœmeri Barr.	...	r	c	...	...	c	...
Monograptus scanicus Tullb.	...	c	c	...	...	...	...
Monograptus tumescens Wood	...	...	c	c	...	...	...
,, ,, var. *minor* M'Coy	...	...	c	c	...	...	...
Monograptus ultimus Perner	...	...	...	...	r	...	...
Monograptus uncinatus var. *micropoma* Jækel	...	r	...	...	...	R	...
Monograptus uncinatus var. *orbatus* Wood	...	r	...	...	...	...	...
Monograptus varians Wood	...	c	...	...	...	...	...
,, ,, var. *α* Wood	...	r	...	...	...	...	...
,, ,, ,, *β* Wood	...	c	...	...	...	...	...
,, ,, var. *pumilus* Wood	...	C	C	...	...	c	...
Monograptus vulgaris Wood	C	...	...	...	...	...	...
,, ,, var. *α* Wood	...	c	...	...	...	...	...
,, ,, ,, *β* Wood	...	r	...	...	...	...	...
Monograptus wandalensis, sp. nov.	...	...	...	...	...	C	...
Retiolites nassa Holm	r	...	...	...	...	c	...
Retiolites spinosus Wood	...	C	...	...	...	...	...

TABLE V (*continued*).

Species and Varieties. C = very common. c = common. R = very rare. r = rare.	WALES and the WELSH BORDERLAND.						CAUTLEY and RAVENSTONEDALE.			
	Wenlock.						Wenlock.			
	Zone of *Cyrtograptus murchisoni.*	Zone of *Monograptus riccartonensis.*	Zone of *Cyrtograptus symmetricus.*	Zone of *Cyrtograptus linnarssoni.*	Zone of *Cyrtograptus rigidus.*	Zone of *Cyrtograptus lundgreni.*	Zone of *Cyrtograptus murchisoni.*	Zone of *Monograptus riccartonensis.*	Zone of *Cyrtograptus rigidus.*	Zone of *Cyrtograptus lundgreni.*
Cyrtograptus carruthersi Lapw.	...	...	...	...	...	C	...	...	...	r
Cyrtograptus flaccidus Tullb.	...	C	...	...	...	...	...	...	...	...
Cyrtograptus linnarssoni Lapw.	...	...	...	C	...	...	...	...	C	...
Cyrtograptus lundgreni Tullb.	...	...	...	...	...	C	...	...	...	C
Cyrtograptus murchisoni Carr.	C	...	...	...	...	...	C	...	...	...
,, ,, var. *crassiusculus* Tullb.	c	...	...	...	...	...	c	...	...	...
Cyrtograptus rigidus Tullb.	...	...	...	...	C	r	...	...	C	...
Cyrtograptus symmetricus Elles	...	...	C	...	...	...	...	...	...	...
Cyrtograptus tubuliferus Perner	...	...	...	...	...	R	...	...	...	...
Monograptus basilicus Lapw.	c	c	c	c	c	c	...	...	...	...
Monograptus capillaceus Tullb.	...	C	...	...	...	...	...	r	r	...
Monograptus dubius Suess	...	r	C	C	C	C	...	C	C	C
Monograptus flemingii Salt var. δ Elles	...	...	...	...	...	C	...	...	...	C
,, ,, ,, ,, γ ,,	...	...	...	...	...	C	...	...	...	C
,, ,, ,, ,, β ,,	...	...	...	...	r	R	...	...	c	r
,, ,, ,, ,, α ,,	...	...	r	c	C	r	...	...	C	r
Monograptus flexilis Elles	...	...	...	C	...	...	...	R	C	...
Monograptus hisingeri Carr. var.	C	c	c	c	c	c	r	C	C	r
Monograptus irfonensis Elles	...	...	...	...	...	C	...	...	...	r
Monograptus jækeli Perner	...	...	...	r	...	...	...	...	...	...
Monograptus priodon Bronn	C	c	c	r	...	...	C	...	...	...
Monograptus retroflexus Tullb.	...	...	...	...	C	...	...	...	...	...
Monograptus riccartonensis Lapw.	R	C	R	...	...	...	...	C	...	...
Monograptus testis Barr., var. *inornatus* Elles	...	...	...	...	...	R	...	...	...	...
Monograptus vomerinus Nich. var. α Elles	C	C	C	C	C	C	C	C	C	C
,, ,, ,, ,, β ,,	C	r	r	...	...	...	c	c	c	...
Retiolites geinitzianus Barr.	C	...	...	...	...	...	C	...	...	...
Retiolites spinosus Wood	...	...	...	...	...	...	...	c	C	...
Retiolites sp.	...	...	...	R	...	...	...	...	...	...
Stomatograptus sp.	r	...	...	...	...	...	...	...	...	...

In conclusion, we wish to point out the close similarity between Tullberg's zonal classification of the Wenlock Shales of Southern Sweden and the Cautley zones (see Table VI, p. 234).

(2) The Ludlow Beds.

We have been able to distinguish two zones only in the Howgill Fells, those of *Monograptus nilssoni* and *M. leintwardinensis*: the watershed of the Howgill area is occupied by rocks which are so unfossiliferous that the evidence obtained from that region is insufficient to permit the establishment of any zone. We have, therefore, included it in the upper part of the *M.-nilssoni* Zone. It may possibly represent the *M.-scanicus* and *M.-tumescens* Zones found by Mrs. Shakespear in Wales and the Welsh Borderland. It is of interest to note that *M. bohemicus* is a far more characteristic fossil of the first zone than *M. nilssoni*. The similarity between this area and the Lake District has already been pointed out (p. 228).

TABLE VI.—CORRELATION OF THE SALOPIAN ROCKS.

Cautley.	Welsh Borders.	Southern Sweden.
Zone of *Monograptus leintwardinensis.*	Zone of *M. leintwardinensis.*	
Grits and flags ?=	Zone of *M. tumescens.*	
	Zone of *M. scanicus.*	
Zone of *Monograptus nilssoni.*	Zone of *M. nilssoni.*	
Zone of *Phacops obtusicaudatus.* (?)=	Zone of *M. vulgaris.*	
Zone of *Cyrtograptus lundgreni.*	Zone of *C. lundgreni.*	Zone of *C. carruthersi.*
Zone of *Cyrtograptus rigidus.*	Zone of *C. rigidus.*	Zone of *C. rigidus.*
	Zone of *C. linnarssoni.*	
	Zone of *C. symmetricus.*	Zone of *M. riccartonensis.*
Zone of *Monograptus riccartonensis.*	Zone of *M. riccartonensis.*	
Zone of *Cyrtograptus murchisoni.*	Zone of *C. murchisoni.*	Zone of *C. murchisoni.*

V. PALÆONTOLOGY.

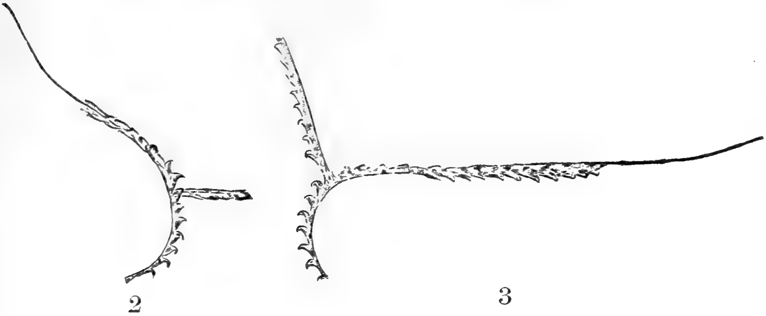
CYRTOGRAPTUS RIGIDUS, Tullb. (figs. 2 & 3, p. 235).

Our specimens of this Cyrtograptid are intermediate in form between *C. rigidus* and *C. symmetricus*; we find that the branching almost invariably occurs at the seventh or eighth theca, and that the first nine thecæ are of the proximal type: these characters constitute a slight divergence from both *C. rigidus* and *C. symmetricus*.

Several specimens show prolongation of the virgula in both branches. It has seemed best, however, to adhere to the name first given by Tullberg, since in general form our specimens agree

with the one most completely figured by him in 'Skånes Graptoliter' pt. ii, 1883, pl. iv, fig. 12. Previously[1] we have called this species *C. symmetricus*, Elles.

Figs. 2 & 3.—Cyrtograptus rigidus, *Tullb.* ×2.

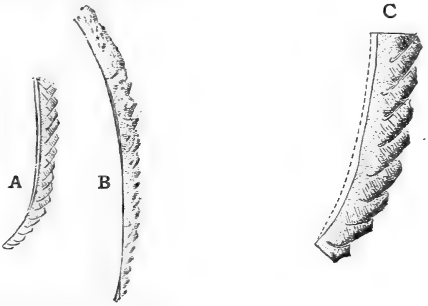


[2, coll. J. E. Marr; 3, from Near Gill.]

MONOGRAPTUS WANDALENSIS, sp. nov. (fig. 4).

Polypary.—Maximum length observed = 2·5 mm.; width at proximal extremity = 0·5 mm., increasing to a maximum of 1·5 mm. at the distal end. Curvature dorsal, variable in amount, in some specimens much marked at the proximal end.

Fig. 4.—Monograptus wandalensis, *sp. nov.*, *rom Wandale Hill.*



[A=Proximal extremity, ×2; B=Proximal extremity, showing part of sicula, × 2; C=distal thecæ, showing growth-lines, × 5.]

Thecæ.—Thirteen in 1 cm.; inclined to the axis at an angle of 35°. The thecæ show a tendency to narrow towards the aperture. Apertural margin concave. Overlap of thecæ a half to two-thirds of their length.

This form may be readily distinguished from all other Ludlow

---

[1] Geol. Mag. dec. 5, vol. vii (1910) p. 473.

graptolites by the marked dorsal curvature conspicuous throughout its length.

Locality, etc.—Wandale Hill, zone of *M. nilssoni*; associated with *M. bohemicus*, *M. nilssoni*, and *M. colonus*.

In conclusion, we wish to express our gratitude to Dr. Marr for all the advice and encouragement which he has given us throughout. We also wish to thank Prof. Charles Lapworth for the interest which he has shown in our work; Mrs. Shakespear for help in the identification of fossils and for the drawings of the graptolites figured in this paper; and Miss G. L. Elles, D.Sc., for much help in the past.

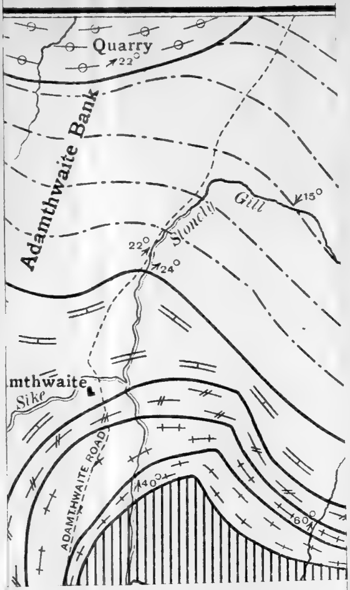
EXPLANATION OF PLATE XII.

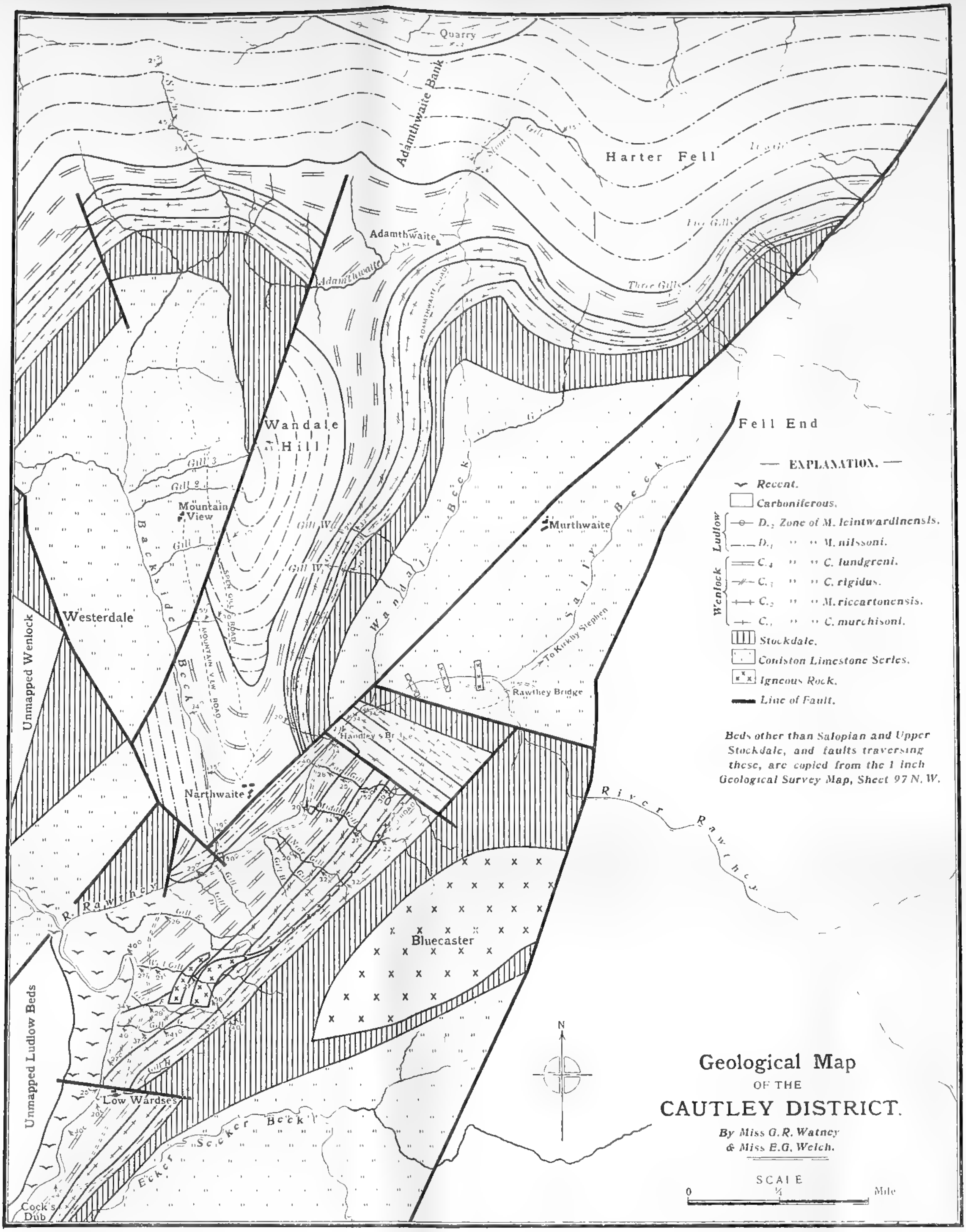
Geological map of the Cautley and Ravenstonedale area, on the scale of 3 inches to the mile, or 1 : 21,120.

DISCUSSION.

Prof. T. McKENNY HUGHES thought that the Fellows of the Society would be best able to realize the difficulties with which the Authors had been confronted, if they were to imagine that the Eastern Counties had been upheaved some 2000 feet, and that deep valleys and bays and inlets had been cut through the newer rocks, exposing the floor of older rocks below, which had been folded and faulted and altered; and that the parts under observation consisted of rocks differing little in detail of lithological character through great thicknesses, while fossils were scarce and badly preserved. Such represented very fairly the problem which the Authors had attempted to solve when they undertook to determine the sequence and distinguish the zones in the Silurian rocks exposed by denudation in the deep valleys cut through the Carboniferous rocks of West Yorkshire.

Edward Forbes had explained the importance of taking representative forms in classifying strata by their fossil contents, pointing out that percentages of fossils in common did not furnish a basis for correlation, unless the forms were identical or representative—that was, if nothing but trilobites had been found in the one, and nothing but brachiopods in the other, and there were not a species in common, still the beds might not be remote in age. The Authors, as might be seen in their tabular synopsis, had recognized the importance of this as far as was possible in the circumstances, and had taken various species of graptolites as characteristic of zones. It was obviously not a pedigree, and it remained to be found out where the variations arose and why new forms took the place of the old. Here again the speaker wished to call attention to the difficulties of the work. Graptolites were hard to find, especially when the beds had been cleaved and altered, and the sheen of rain was on the rock.


Quarry
22°
Adamthwaite Bank
Stonely Gill
15°
22°
24°
mthwaite
Sike
ADAMTHWAITE ROAD
40°
60°



Beds other than Salopian and Upper Stockdale, and faults traversing these, are copied from the 1 inch Geological Survey Map, Sheet 97 N. W.

Geological Map
OF THE
CAUTLEY DISTRICT.

By Miss G. R. Watney
& Miss E. G. Welch.

The index to the map began with the Coniston Limestone Series. The speaker had cut off the upper part of this under the name of Fairy Gill Shale, which was the equivalent of that so well described by Dr. Marr in the adjoining Lake District as Ashgillian. There was a troublesome fossil at this horizon, the difficulty in respect of which Davidson left unsolved. This was *Strophomena siluriana*, which had not yet been satisfactorily distinguished from the *Orthis hirnantensis* of the upper or proper Hirnant Limestone, which the speaker would regard as the equivalent of the very variable base of the next division in the Authors' index—namely, the Stockdale Shale, which forms the basement-bed of the Silurian.

The Authors had attacked principally the enormous overlying series of rocks, which, sometimes more sometimes less sandy, but rarely justifying the name of grit, appeared to be the Northern Type corresponding to the Wenlock and Ludlow of South Wales. They had not here, as in the case of the Southern Type, well-marked limestones (the Woolhope, the Wenlock, and the Aymestry Limestones) to help them to run lines across an obscure country; but, by working out the graptolithic fauna of every available exposure, they had succeeded in correlating the sequence with that of other better-known areas, especially with that of Scandinavia. Such a work required great knowledge, care, and staying power, qualities by which the Authors had made a notable advance in geological research.

Dr. Marr, replying, in the absence of the Authors, remarked that there was nothing to answer, but that he wished, as one who knew the district, to express his satisfaction with the detailed and accurate results obtained in an area where, owing to the somewhat monotonous uniformity of lithological characters, separation of the zones by such characters was almost impossible until the fossil horizons had been determined in the manner pursued by the Authors.

7. *Some* OBSERVATIONS *on the* EASTERN DESERT *of* EGYPT; *with* CONSIDERATIONS *bearing upon the* ORIGIN *of the* BRITISH TRIAS. By ARTHUR WADE, B.Sc., A.R.C.S., F.G.S. (Read March 22nd, 1911.)

[PLATES XIII–XVI.]

CONTENTS.

I. INTRODUCTION.

DURING the past two years I have on several occasions visited that part of the Eastern Desert of Egypt which borders the Red Sea near its junction with the Gulf of Suez. While there I made observations of desert conditions and phenomena which appeared to me to be of interest to the student of the conditions determining the origin of the Triassic rocks of Britain.

A few years ago the late J. Lomas[1] dealt very fully with these conditions, having made some studies of South African and Egyptian deserts, and it is with pleasure that I find myself able to confirm or to supplement several of the conclusions to which he came.

II. THE IGNEOUS 'GRAVELS' AND PEBBLE-BEDS.

The western side of the Red Sea is flanked by a wall of hills running generally in lines parallel with the general trend of the coast. They rise abruptly from a level or gently sloping coast-plain, which varies in width from under 1 to over 10 miles. The hills are composed chiefly of igneous rocks: red and grey granites, dark andesites and purple porphyries, with some tracts of gneiss and schist.

At the foot of the hills, large mounds of angular débris of the igneous rocks occur, running in tongues from the hills out on to the plain, or forming low foot-hills which run parallel with the main range.

---

[1] 'Desert Conditions & the Origin of the British Trias' Proc. Liverp. Geol. Soc. vol. x, pt. 3 (1906–1907) pp. 172–97.

The mounds themselves consist of unsorted angular blocks and flakes varying greatly in size, and showing as a rule no signs of stratification where cut through. The rocks of which they are composed are always similar to those of the igneous range nearest to which they rest.

The mounds contain very little sand, and such as is present has obviously been introduced by the subsequent action of wind. Measurements taken by means of the aneroid showed that these mounds rose abruptly from the coast-plain just below the 100-foot contour, and that their summits, as a rule, varied in height between 120 and 160 feet above sea-level.

The mounds and ridges of igneous débris flank the eastern slopes of the hills throughout their length; and, when viewed from a distant position, they are seen to be remarkably even in height and to be of the nature of a platform or terrace, broken in places by wadis and gullies (see Pl. XIII).

In dealing with the geology of the Eastern Desert, the late Mr. Barron remarked that

> 'the plains east of the Red Sea Hills are largely formed by gravel ridges extending from the mountains, and composed of materials derived from them or from the lower parallel ranges....'[1]

It is a remarkable fact that these 'gravel'-mounds[2] show their greatest development where the hills are unbroken. Wherever gullies or wadis occur, they are either cut through or else they are entirely absent *(loc. cit.)*. On the south side of the Gulf of Jemsa a large area is covered by mounds of this material, separated from the hills by a narrow sandy depression.

III. Origin of the Igneous 'Gravels.'

In the work cited, the Egyptian Government Surveyors say very little with regard to the origin of these mounds of 'gravel' on the eastern side of the Red-Sea Hills, although they express opinions with regard to the igneous 'gravels' that are found on the western side of those hills and in the Nile Valley, which show important differences and associations.[3]

The hills are covered with angular fragments of all sizes, produced by the forces of disintegration common to such regions.[4] The mounds in question are not, however, of the nature of screes. True screes do occur on the hills, but they were not usually connected intimately with the igneous 'gravels.' As a rule, the 'gravels' are separated from the hills by a narrow depression partly filled

---

[1] T. Barron & W. F. Hume, 'Topography & Geology of the Eastern Desert of Egypt: Central Portion' Egypt. Geol. Surv. Rep. 1902, p. 126.

[2] The term 'gravel' has been used very largely, in connexion with these beds, by Egyptian geologists. For that reason I have retained it.

[3] T. Barron & W. F. Hume, *op. cit.* pp. 128-30.

[4] See J. Walther, 'Das Gesetz der Wüstenbildung in Gegenwart & Vorzeit' Berlin, 1900.

with sand. Neither does it seem probable that these beds could have been formed as a result of the torrential rains which sometimes occur in these hills. Such rains are very violent at times, and the great volume of water resulting from them produces astonishing effects in the gullies. The torrents, however, rather tend to cut through and to destroy the mounds than to create them, and the general effect of the rains which occurred while I was in the desert seemed to be to slope off the cliff-like terminations of the 'gravel'-mounds, and to distribute their materials farther over the plains. Moreover, such action would not easily explain the existence of the mounds which lie at some distance from the main hills, such as those south of the Gulf of Jemsa; nor will it account for their plateau or terrace-like characters. Glacial action might possibly account for some of the principal features; but no signs of glacial action have ever been noted by any of the travellers who have explored the hills of the Eastern Desert.

Some clue may be obtained from a consideration of what is now taking place along this coast. Three distinct raised beaches are recognizable, both at Abu Sha'ar and on the coast near Jebel Zeit[1]; while a study of the islands off the coast shows that four or even more periods of marked elevation have occurred within comparatively recent times. One beach, at a height of over 80 feet, corresponds very closely with the level at which the mounds usually begin: this is well shown at Jebel Zeit. Again, in places, the igneous fragments are cemented together by a calcareous cement which contains marine fossils of Pleistocene age.[2] Occasionally, beds of coarse limestone are associated with them; while among the angular fragments of the 'gravels,' broken shells of recent Red-Sea types may sometimes be found. Finally, we may note the peculiar manner in which the plain runs right up to the base of the ['gravel'] hills, 'against which it stops abruptly like a beach against a cliff.'[3]

All the foregoing observations point to the conclusion that these beds are talus-heaps, derived from the eastern slopes of the Red-Sea Hills by the action of the sea-waves beating against their cliffs and slopes.

The rapid rise of this coast and the very insignificant action of the tides in this part of the Red Sea are sufficient to explain the absence of rounding in most localities, although this absence is not invariable. Conditions favourable to the rounding of the pebbles occurred in places, probably where strong currents were active. The sharp turn in the coast at Jebel Zeit appears to have been such a place, and beds of rounded pebbles here reach a height of nearly 330 feet.

---

[1] T. Barron & W. F. Hume, Egypt. Geol. Surv. Rep. 1902, pp. 123–25.

[2] *Ibid.* p. 126.

[3] *Ibid.* p. 70.

IV. THE SANDY 'GRAVELS.'

Where the ridges and mounds touch the coast-plain, there is an abrupt change in slope as well as a change in the formation. The plain shelves gently off towards the sea; and, although it is covered with loose stones and angular boulders derived from the material of the mounds, there is a predominance of sand, which increases seawards until nothing remains but the sands of the shore impregnated with salt or gypsum. The 'gravels' in which the sand predominates largely are very different, both in structure and in origin, from the igneous 'gravels' with which I have just dealt. They owe their present characters largely to the action of rain and storm waters upon the mounds of coarser material and upon the hills themselves. They are, in fact, formed by the overlapping of ordinary fan-taluses originating in the numerous wadis which cut through the hills. This is beautifully shown under the wadis cutting through the Jebel Zeit range, where these fan-taluses reach huge dimensions and are almost perfect in their outlines. These sandy 'gravels' are intersected in almost all directions by a network of watercourses (Pl. XIV, fig. 1). There is, of course, a distinct rise in level opposite the mouths of the wadis—contrasting with the behaviour of the coarse 'gravels,' which are cut away or altogether absent.

Where the watercourses have formed a cliff like those seen sometimes in the mounds, a distinct bedded arrangement is observable, which is never seen in the 'gravel'-cliffs. Such a cliff is to be seen in the mouth of the large unnamed wadi south of the Wadi Mellaha. The arrangement is of the nature of current-bedding; but this structure was shown on a large scale in shafts and trenches made in the material of the plain itself. In these the beds of pebbles varied greatly in thickness, from little strings of small pebbles to coarse beds of pebbles and sand a few feet thick. The bedding-planes were sometimes marked by a more perfect cementation of the sand-grains, causing the lines of bedding to stand out from the sides of the section after it had been left some time. The sand was loose and imperfectly consolidated throughout. The mode of origin suggested by Lomas[1] for some at least of the Triassic current-bedding is here demonstrated. The old channels are filling with sand; in some cases they are completely filled, and so, during the next rainy season, the new channels may take courses which differ in position, in depth, or in both from those which existed before.

V. PARALLELS IN TRIAS AND PERMIAN.

Parallels to nearly every feature described can be seen in the Bunter Beds. The masses of pebbles with comparatively little sand found in the Midlands; the sand with pebble horizons sometimes only a few inches thick, sometimes increasing to 3 or 4 feet in

---

[1] Proc. Liverp. Geol. Soc. vol. x, pt. 3 (1906–1907) p. 175.

thickness, common in the Bunter Pebble-Beds of Lancashire and Cheshire; the angular breccias of Hilbre Island, and so on; even the striking eccentricity of the bedding-planes, as well as other minor features, are all characteristic both of the Triassic pebble-beds and of the 'gravels' of the Red-Sea coasts.

The Permian conglomerates of Shropshire and South Staffordshire[1] appear to show close resemblances with the coarse beds here described. Calcareous conglomerates and breccias of igneous rocks, which pass into more sandy beds, have been described; while Prof. Hull[2] has expressed an opinion that these beds originated in the very manner that I have suggested for the Red-Sea igneous 'gravels.'

VI. Distribution of Pebbles.

Despite the fact that the conditions already described will explain many points in Triassic geography, those observers who account for the distribution of pebbles in the Triassic Pebble-Beds, by transportation by means of a large river, receive some support from a study of the 'gravels' on the western side of the Red-Sea Hills. That a river should carry stones of moderate size for a distance of 300 miles or more has seemed to be impossible.

I have already shown that, on the eastern side of the Red-Sea ranges, the fragments found in the 'gravels' are derived from the hills near to which they lie, and that they have travelled very little in most cases. A similar state of things is observed in certain localities in England, where the pebbles of the Bunter Beds can be traced to neighbouring Mountain Limestones, cherts, sandstones, and even veinstones. Fragments in the Permian breccias of Staffordshire have also a local origin.

On the western side of the igneous hills of the Red-Sea coast a different set of circumstances has affected the distribution of the rock-fragments; they appear to have been carried along the main wadis and old lines of drainage, to distances which compare very well with those to which some of the more widespread pebbles—such as the liver-coloured quartzites—in the British Bunter Beds may have been borne.

The distribution of these rocks from the igneous ranges of the Red-Sea districts in the gravels of the valley of the Nile and adjoining areas is shown very well in the accompanying sketch-map (fig. 1, p. 243), which I have constructed from details given by Barron & Hume.[3] These authors trace the pebbles from four main centres of distribution:—

(1) Jurra-Jidami Range	Granite.
(2) M eteq Range	Gneiss.
(3) Jebel Abu Garahish	Schist.
(4) ri District	Schist.

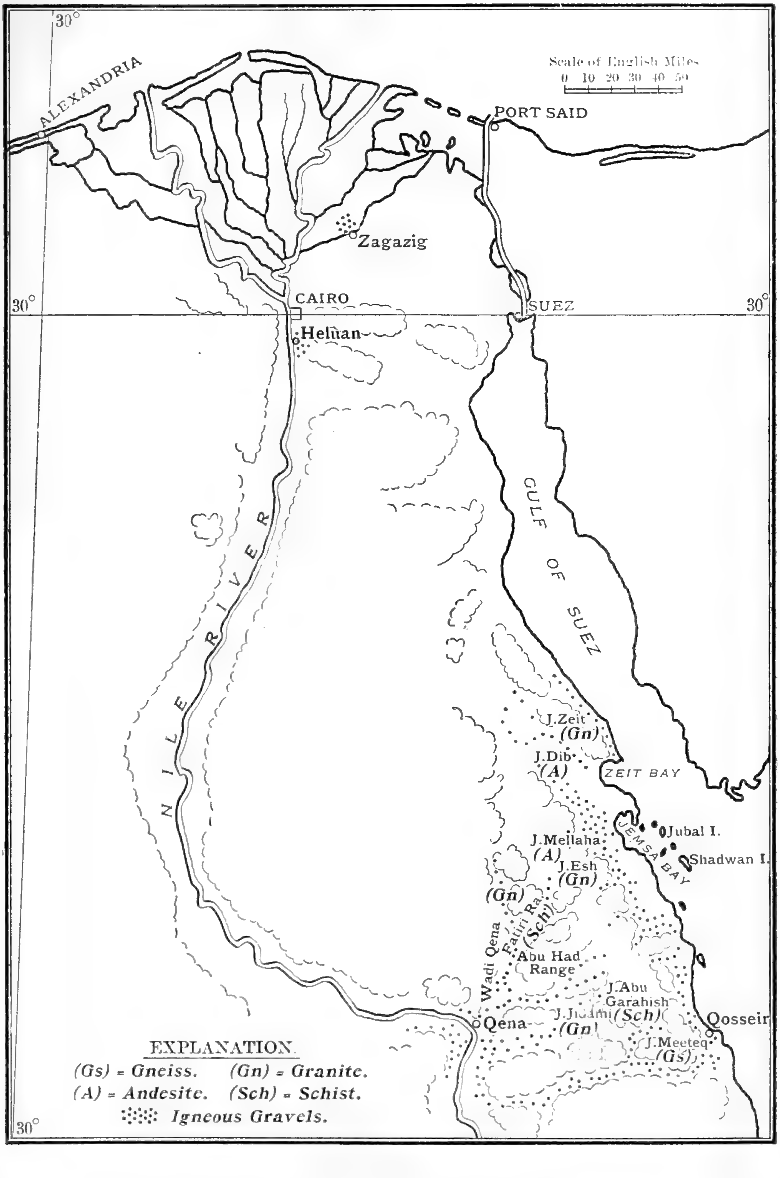
---

[1] W. Wickham King, Q. J. G. S. vol. lv (1899) p. 97.

[2] 'The Triassic & Permian Rocks of the Midland Counties of England' Mem. Geol. Surv. 1869, pp. 14 *et seqq.*

[3] Egypt. Geol. Surv. Rep. 1902, pp. 121 *et seqq.*

Fig. 1.—*Map of Egypt, showing the distribution of the 'gravels' containing igneous rocks derived from the Red-Sea Hills.*



The pebbles have travelled in more or less westerly directions down the wadis, into the important north-and-south wadi which continues the line of the Nile north from Qena. They are abundant for some distance to the north and south of Qena. Thence they have been carried northwards down the Nile Valley. They were found by Mr. Beadnell[1] on the western side of the Nile, this fact having been used in the determination of the age of that river. The most interesting occurrences of these rocks, which the Survey geologists say 'could only come from the Red Sea',[2] are at Heluan, a few miles south of Cairo, where they were noted by Mr. Beadnell, and in the Delta itself, where they were found in the Royal Society's boring at Zagazig.[3] Thus these rocks have been river-borne for at least 400 miles.

A careful examination of the Jubal and Gaysum groups of islands showed that these 'gravels' do not exist upon them. This suggests that these islands have come into existence since Pleistocene times, the age generally assigned to the 'gravels.'

A very thin bed of 'gravel,' containing pebbles of igneous rocks, does occur beneath the Upper White Limestone Series on Jubal Island. The pebbles are evidently derived from the igneous rocks of the mainland, and consist of pink granite, felsite, andesites, and porphyries. Since the age of the limestone ranges perhaps from Upper Miocene to Pleistocene, the presence of this gravel suggests a local extension of the land-area at some time immediately prior to those periods. This has an important bearing upon the sequel.

VII. Sands and Marls.

The Gulf of Suez, with its parallel ranges of hills, appears to act as a funnel down which cooled air from the north is drawn towards the Equator. Thus there is an almost constant northerly wind, which frequently blows with violence.

Zeit Bay and the Gulf of Jemsa are both directly in continuation of sandy tracts of country, from which there is a continuous passage of dust and sand. Both are at certain seasons bordered with saline mud containing very much fine material, along with some coarser sand-grains.[4] The passage of the dust must be checked by the water of these bays, and the fine mud is the result of the accumulation which necessarily takes place under these conditions. Here, then, we have in actual progress the state of things adduced theoretically by Mr. H. C. Beasley[5] to account for the Keuper Marls (so-called) of South Lancashire and Cheshire. In these districts

---

[1] J. W. Dawson, 'Notes on the Geology of the Nile Valley' Geol. Mag. dec. 3, vol. i (1884) p. 289; see also T. Barron & W. F. Hume, Egypt. Geol. Surv. Rep. 1902, p. 121.

[2] T. Barron & W. F. Hume, *op. cit.* p. 128.

[3] J. W. Judd, 'Second Report on a Series of Specimens of the Deposits of the Nile Delta' Proc. Roy. Soc. vol. lxi (1897) p. 32.

[4] T. Barron & W. F. Hume, *op. cit.* pp. 78 & 79.

[5] Proc. Liverp. Geol. Soc. vol. x, pt. 2 (1905–1906) pp. 79 *et seqq.*

these fine deposits are not of the nature of true marls, but consist largely of very fine particles of comminuted quartz,[1] such as certainly form the bulk of desert-dust. The great thickness of the Keuper Marls in Cheshire no longer surprises us, when we see how persistently the dust is at present being blown from the Eastern Desert towards the bays of the Red Sea. The conditions in that sea are not, however, favourable to the accumulation of such thick deposits: for a rapid rising of the sea-bed is in progress, instead of a sinking, which would be necessary for the purpose.

It is probable that true marls are in process of formation beneath the waters of these bays, just as true marls are found in the Keuper beds in other parts of England. In fact, true marls were found in borings north of the Gulf of Jemsa, as well as among the recently raised limestones on Jubal Island. The materials for the formation of the dolomite crystals observed by Dr. Cullis[2] in the Keuper Marls of the Midland and South-Western districts are present in these muds, since analysis[3] revealed the presence of calcium and magnesium salts in their cementing-materials. A careful search for these rhombs was made in the marls—both among those recently elevated on Jubal Island, and among those which are at present forming on the coasts of the Gulf of Jemsa. The material was first allowed to stand in water for 24 hours: the liquid being repeatedly changed, in order to get rid of the soluble salts. In the fine residue of the marls from Jubal Island, myriads of these tiny rhombs were discovered. They were compared, through the kindness of Dr. Cullis, with those found by him in the Keuper Marls. They were undoubtedly similar in shape and other properties, though somewhat smaller in size. The material from the coast of the Gulf of Jemsa was not so satisfactory, though here again the crystals were present, if in smaller numbers. This interesting discovery of dolomite-rhombs, for the first time in recent deposits under desert conditions, goes far to support the contention of Dr. Cullis that the rhombs in the Keuper Marls were formed by actual deposition from supersaturated waters; it also furnishes a further interesting parallel between the conditions of deposit in the Triassic sea and those which obtain in the present Red-Sea area. The results of this investigation are important: they tend to show that, although the Keuper Marls of the Midlands and the West of England were laid down under aqueous conditions, those of the Lancashire and Cheshire areas were laid down nearer to terrestrial conditions, the land probably consisting of low-lying areas bordering inland seas or saline lagoons.

The saline mud on the shores of the Gulf of Jemsa is mostly consolidated, and consists of a hard deposit cemented by means of soluble salts (see p. 252) which are present in a crystalline form. A certain amount of the cementing-material has been re-dissolved, leaving cavities and a honeycomb structure in places. The broken

---

[1] P. Holland & E. Dickson, Proc. Liverp. Geol. Soc. vol. vii (1896–97) p. 443.

[2] Rep. Brit. Assoc. 1907 (Leicester) p. 507.

[3] Tabulated later, p. 252.

material at times shows excellent cubes of salt under the microscope, and many of the hollows appear to have cube-like forms. Footprints, sun-cracks, and wind-ripples impart a Triassic aspect to the sands in places, especially where large sea-birds have left their tracks.

Fig. 2.—*Sand with 'dreikanter,' from the sandy gravel-plains north of the Gulf of Jemsa. (Natural size.)*

Many of the gullies are being filled with sand, and one can easily recognize the sifting effect of the wind. The particles of sand in the deposit at the foot of a gully are much coarser than at the head, and contain numerous flakes of granite and andesite derived from the neighbouring rocks. Here the sand is rather firm: as

one climbs the gully, the sand becomes finer and less firm, until it is so fine and loose that one sinks up to the knees in it. The equilibrium of the mass is very unstable, the slightest jarring causing great masses to slide much like a fluid towards the bottom.

Fig. 3.—*Foraminiferal sand, with abundance of* Orbitolites complanata *Lam. and other organisms. Southern shore of South Gaysum Island. (Natural size.)*

The sands which occur among the gravels in the depression between the Zeit range and the Um-Esh range are of a peculiar character. Very little fine sand occurs, but grains as large as peas, usually 5 to 10 millimetres in diameter, cover large areas in such a manner as to appear as though they had been artificially set. A careful examination of the individual grains showed that

they consisted of almost every type of local rock, quartz-grains slightly predominating. They were all polished and worn, and very frequently facetted so as to form tiny dreikanter (fig. 2, p. 246, & Pl. XV, fig. 1). Dreikanter on so small a scale do not appear to have been previously noted. These large grains are not often carried into the air by the wind; but, when the wind is sufficiently strong, the effect of such flying grains is painful in the extreme, and it is impossible to face them for any length of time. This type of sand owes its character to the sifting action of the wind: the fine sand has all been removed, and is often found filling gullies high up in the hills. It leaves behind these bigger and heavier grains, which are just able to withstand the ordinary force of the wind.

On the islands no siliceous sand is to be found, as a rule. The sands are calcareous, and are chiefly formed from comminuted fragments of corals and shells, as on Jubal Seria; of calcareous algæ, as on the northern side of Gaysum Island; or of foraminifera, as on the southern side of Gaysum Island (fig. 3, p. 247), where *Orbitolites complanata* is the predominant form.

VIII. Effects of Wind-blown Sand.

The action of the wind upon the various rocks was very striking. The softer limestones are sometimes worn into fantastic shapes (Pl. XIV, fig. 2); and sometimes they are regularly grooved in such a manner as often to simulate bedding-planes. The effect of the sand-blast upon soft limestone is nowhere more magnificently shown than on Jubal Island, although the sand there is soft and calcareous. In the limestone-cliffs occur cirques or semicircular bay-like openings, which go far inland, leaving hard outliers, carved into curious shapes, standing near the shore. They vary greatly in width, but are sometimes over 100 yards across. On the sides of these cliffs the fossils stand out in relief, and sometimes present the only means of determining the angle and direction of dip in the massive beds. Similar cirques are described by Barron & Hume[1] on the western side of the limestone outlier of Abu Had: they explain the origin of such cirques as due to the widening of joint- and fault-planes by the sand (Pl. XV, fig. 2). Afterwards the sand-eddies scoop out the hollows thus formed, until wide semicircular recesses are finally formed in the cliffs. On Jubal Island, however, these cirques are connected with raised-beach phenomena, and are certainly of marine origin in their early stages.

The effect of the wind-blown sand upon the harder rocks is somewhat different. The chief action of the sand-blast upon the granite is to assist in the removal of the felspar-crystals from the surface of the rock: these crystals become weakened along the planes of cleavage by the constant expansion and contraction due to the heat of the sun. The outer layers are more affected than the deeper-lying layers, and hence the tendency to flake off at the surface. The quartz stands out in relief all over the surface of the granite, but it soon becomes dislodged in the general break-up of the felspathic

---

[1] *Op. cit.* Egypt. Geol. Surv. Rep. 1902, p. 289.

constituents. A specimen of the granite-surface which I obtained shows this action in a remarkable manner, the quartz-grains standing out in high relief, and the felspars being almost entirely eaten away. The flying sand-grains have been driven on to the softer portions of the rock with such violence, that they are to be seen still wedged firmly into every crevice (see Pl. XVI, fig. 1).

This, however, is not the only way in which the sand assists in the disintegration of the igneous rocks. There is still another phenomenon, which does not appear to have been noted hitherto. The very finest material is forced into the tiniest cracks and crevices in the rocks. Rocks, which at first sight appear to be quite sound, crumble to pieces when struck by the hammer, and all along the shatter-planes will be found this very fine sand penetrating to considerable depths. Here it tends to assist the other agents of disintegration: the action of frost, the alternations of heat and cold, the percolation of moisture, and more rarely the vital forces due to the action of plants and animals. The grains act as tiny wedges, slipping ever farther into the cracks when opportunities occur, until finally the parts are so forced asunder that the rock falls to pieces.

The andesites and porphyries become more polished and grooved than the granites, and show less tendency to crumble. They also are more liable to develop facets where the blowing sand-grains have planed off corners and edges. Sometimes these rocks are grooved all over in a peculiar manner by the action of the wind-blown sand, and resemble exactly the specimens obtained by Prof. Watts[1] from the Triassic rocks of the Charnwood-Forest area. In some specimens, hard zeolites have resisted the action of the wind and stand out all over the surface, capping curious protuberances which look very like collar-studs.[2]

One of the most interesting results of the action of wind-blown sand was observed on Jubal Island. This was the mechanical etching of the crystalline gypsum (selenite) which occurs there. The calcareous sand wears away the faces of the crystals, but its action is selective. The greatest wearing effect seems to be produced in directions parallel to the orthopinacoid (1.0.0.) and the negative hemipyramid (1.1.1.). The result is a beautiful series of etched figures produced mechanically, covering the clinopinacoidal faces of the mineral (see Pl. XVI, fig. 2).

Other phenomena, due to wind-blown sand, such as the formation of dreikanter, have been dealt with elsewhere.[3] The action of the sun upon the flints and cherts derived from the Eocene limestones is worthy of note. The surfaces of such flints are usually chipped all over, owing to small fragments having broken off with a conchoidal fracture, and sometimes the fracture has left perfect cones on the surfaces. In such cases, the angle of slope of the cone was usually found to lie between 30° and 35°.

---

[1] W. W. Watts, Rep. Brit. Assoc. 1899 (Dover) p. 747.

[2] Mr. T. O. Bosworth has also used this simile, in describing comparable occurrences on the coast of Mull, Geol. Mag. dec. 5, vol. vii (1910) p. 354.

[3] Geol. Mag. dec. 5, vol. vii (1910) p. 394.

IX. ORIGIN OF THE SAND.

With a view to discovery, if possible, of some clue to the origin of the sand on the desert and in the hills, I examined a series of samples from various localities. One series was especially collected from the shore, one from the centre of the plain, and one from the gullies in the hills.

Prof. Walther,[1] in his work on the physiography of this desert, says that the chief source of the sand is the granite area. Barron & Hume[2] disagree with this, and claim the Nubian-Sandstone areas as the source of origin. They do this, not on account of the mineral composition of the sand, but because of the abundance of sand in those areas and its absence in the midst of the granite hills. They specifically mention the tract that I examined in detail, as being one towards which the sand is being continually blown from a Nubian-Sandstone area. This may account for some part of the sand present along the eastern side of the Mellaha-Esh ranges, but the microscope does not, in the main, support their contentions: it rather justifies, indeed, Prof. Walther's statement. I append the results of microscopic examination of four samples of sand, the last of which was taken from the base of a Nubian-Sandstone escarpment.

No. 1 Sample.—Salt-caked sand from the western shore of the Gulf of Jemsa, consisting of large rounded grains mingled with very fine particles of dust, made up chiefly of fairly angular quartzose material. The large grains are well rounded, and include quartz, pink felspar, some cream-coloured felspar, and a little green epidote. Flakes of biotite are common: they are somewhat altered, and present a very metallic appearance. More angular grains or tiny flakes of a black rock, resembling the dark andesitic rock of the hills nearest the shore, and one or two subangular fragments of a purplish-brown rock were present. A few tiny needles, probably of apatite, occur also, as well as some tiny rhombs showing a faint high refractive index and assuredly not of an isotropic mineral. These latter are almost certainly dolomite. The biggest grains observed had a diameter of 2·5 mm., though 1·5 mm. was a more usual size.

Foraminifera are fairly plentiful, forms apparently assignable to *Rotalia* and *Textularia* being discernible.

No. 2 Sample.—Loose sand filling a watercourse, half a mile from the shore.

This sand was much finer throughout than that of Sample 1. The same abundance of well-rounded pink felspar is present, with much colourless quartz. Very many dark and even black grains are present, some of which are slightly magnetic. An altered brassy-looking mica occurs here in tiny flakes.

No. 3 Sample.—Obtained near the foot of a gully in the hills, about a mile west of the Gulf of Jemsa.

Here the grains vary greatly in size. They range in diameter between 0·75 mm. and the finest dust. The sand contains all the minerals observed in Samples 1 & 2, together with small angular flakes of the black rock measuring up to 1 cm. in diameter. Here, again, the pink

---

[1] 'Ueber Ergebnisse einer Forschungsreise auf der Sinaihalbinsel & in der Arabischen Wüste' Verhandl. Gesellsch. f. Erdkunde Berlin, vol. xv (1888) p. 244.

[2] *Op. cit.* Egypt. Geol. Surv. Rep. 1902, p. 288.

felspars are among the best rounded of the grains, while the black grains are very angular. Wind-carried foraminifera are present in this sand.

On treating the sand with acid, I found that some calcareous particles are present. I also found in this sand some purple grains, which are probably derived from the porphyries of the Mellaha range.

No. 4 Sample.—Sand from the base of the Nubian-Sandstone escarpment, Zeit range.

This sand consists almost entirely of colourless quartz-grains. Some cloudy grains occur, which probably are milky quartz. A few grains of somewhat altered mica are seen. The sand is more purely quartzose than any of the other samples. The grains are rounded to subangular, and are fairly even in size.

A noteworthy feature is the way in which the felspars are rounded into sand-grains. The dry disintegration seems to result in very little chemical alteration, the effect being almost entirely physical. As a result, felspar is a common constituent of these sands.

I have already shown that the big sand-grains found in the desert between the Um-Esh and the Zeit ranges are derived from every type of local rock, and are intimately connected with the 'gravels' in composition and in origin.

It thus appears that the sands along this belt, at any rate, are in the main derived from the break-up of the local rocks: including chiefly the granite, and to a smaller extent the andesitic rocks and porphyries. The granite, where exposed, can be seen in all stages of decay. Instead of breaking down into flakes, it crumbles away into coarse material, which is readily picked up by the strong winds and soon worn down into sand-grains. It is certain, however, that the Nubian Sandstone does supply some part of the material, although it does not appear that such material predominates.

X. Salt and Gypsum.

In studying these deposits, it is best to deal with them under two heads:—

(*a*) The deposits now in process of formation.
(*b*) The older deposits, such as are found in borings or in outcrops at the surface.

(*a*) The first type of salt-deposit was best seen in process of formation on the western side of the Gulf of Jemsa. At this place the gulf is bordered by a shallow depression, very little above the highest tides that we observed. The depression runs in a series of crescentic outlines for a considerable distance along the coast. It is filled with a deposit of snow-white salt crystals to a thickness in places exceeding 1 inch. This deposit was evidently due to the evaporation of sea-water which had at some time flowed into it during a higher tide than usual, or had been driven into it by a favourable wind. The hardened saline mud found along the borders of the gulf, and also at the southern end of Zeit Bay, has already been described (p. 245). This occurrence reminds one of the similar phenomena noted in the Keuper Marls of the Lancashire

and Cheshire districts. It may be that the presence of the salt is not entirely due to the evaporation of a sea-water film. All along the edge of the sea was a white spume which accumulated continuously from the air-bubbles left behind by retreating waves. This frothy material was intensely salt. After standing some time, the water partly evaporated, leaving behind a more saline and sticky white mass, which was constantly being blown inland over the sand. In this manner enormous quantities of salt must be carried inland, and deposited among the sands of the desert.[1] Sometimes stones were found at some distance from the sea, coated with a pure white encrustation of salt: in these cases the salt had evidently been carried inland by the wind. On the northern coast of Gaysum Island several patches of snow-white salt crystals, perfectly formed and frequently measuring 5 to 10 mm. in diameter, are to be seen at a height of 20 to 30 feet above sea-level. Here, again, the salt was carried in as foam. Saline encrustations were found on the fossils of the raised coral-reefs of the Jubal group of islands, almost 200 feet above sea-level.

I append analyses made of the saline sand from the shores of the Gulf of Jemsa. (The spectroscope revealed the presence of abundant sodium with some calcium. Potassium was faintly indicated.)

I. Bulk Analysis.	*Sample No. 1.* Per cent.	*Sample No. 2.* Per cent.
Na_2O (with some K_2O)	25·02	23·40
CaO	3·43	5·14
MgO	1·47	1·42
Fe_2O_3	2·40	9·90
SiO_2	33·20	23·78
Cl	28·52	30·80
SO_3	4·85	4·52
CO_2	3·12	......
H_2O	1·74	6·76
Totals	103·75	105·72

Sample No. 1.

II.	
Matter removed by solution in warm dilute HCl...	61·91
Residue insoluble in dilute HCl	34·20
H_2O	1·74
CO_2	3·10
Total	100·95

Sample No. 2.

II. Water extract.	
CaO	2·14
Na_2O	23·40
Cl	30·80
MgO	trace
Acid extract.	
SiO_2	23·78
CaO	3·00
Fe_2O_3	9·90
MgO	1·42
SO_3	4·42

[The results total more than 100 per cent., because the sodium is returned as oxide. The amount of sodium in Sample 2 is equivalent to 26·50 per cent. of sodium chloride, and the calcium oxide in the soluble portion is equivalent to 4·25 per cent. of calcium chloride.]

---

[1] See J. G. Goodchild, 'Desert Conditions in Britain' Trans. Geol. Soc. Glasgow, vol. xi (1897–1900) p. 85.

The foregoing analyses show that only about a third of the rock consists of sand, the remaining two-thirds consisting of soluble salts. A fair amount of gypsum and magnesium salts is indicated along with the rock-salt in the deposits, as would have been expected in the circumstances.

Both the Gulf of Jemsa and Zeit Bay are continuations of low tracts of sandy and gravelly desert which lie to the north of them. Where these tracts meet the sea there salt marshes exist. In examining the country at the head of the Gulf of Jemsa, I found that the marsh gradually gave place to firm ground as one proceeded landwards. But another change took place: the cementing-material was now gypsum and not salt. The desert was curiously marked by low concentric ridges only an inch or two high, which ran somewhat parallel to the shore-line, as well as to the borders of higher tracts of ground; they suggested lines left by the gradual desiccation of a shallow pool of water. The ridges were covered with aggregates of gypsum crystals, some of which reached 5 or 6 centimetres in length. When the ground was dug into, it was found to be very moist underneath. A little farther north the sandy desert presented a curious appearance, being covered with a network of projecting veins of gypsum. These stood out sometimes 6 inches or more from the surface, owing to the fact that they seem to resist the wind—the sand in between the veins having been removed by that agency. Similar veins are sometimes very abundant in the recent limestone of the Gaysum Islands.

Again, on South Gaysum Island, the surface in the centre of the southern part of the island was found to consist entirely of gypsum crystals. When the deposit was dug into, the gypsum was found to be present in stout fibrous crystals closely packed together, which penetrated from 6 to 12 inches or more below the surface. When traced in any direction, the gypsum deposit was seen to merge insensibly into raised coral-beach or shelly and foraminiferal sands. The deposit itself contained practically no organic remains; it is evidently in process of formation, at the expense of the more normal deposits. It appears, then, that both here and at the head of the Gulf of Jemsa and of Zeit Bay the sea-water is being drawn up by capillarity into the huge deposits of fine sand which there exist. The gypsum seems to be deposited there by this action, the salt probably being retained in solution. Where the sands are siliceous, the result is the formation of gypsum crystals among the sand at the surface. Where the sands are calcareous, the change seems to be accompanied by a metasomatic replacement in the calcareous matter, resulting in the destruction of organic remains. That the shells of the raised coral-reefs do tend to become converted into gypsum was proved by an analysis of a shell taken from the raised reef of Jubal Seria. This yielded the following result:—

	Per cent.
$CaCO_3$ .... about	60
$CaSO_4$	20
Other salts, chiefly sodium chloride and salts of magnesium	20

An analysis of the 'gypsumized' beds of South Gaysum Island gave the following result:—

	Per cent.
CaO	30·20
SiO_2	2·14
Na_2O	2·35
CO_2	1·72
SO_3	39·38
H_2O	21·50
Cl	2·69
Total	99·98

If it be held as proved that these raised calcareous beds are thus altered under suitable conditions into gypsum, some difficulties connected with Triassic and more recent Egyptian geology are evidently nearer solution.

A certain amount of encrustation, consisting of soluble salts, occurs upon almost every fossil present on the islands in the Red Sea. In order to determine its character, I carefully removed the encrusting salt from the fossils that I had collected, and subjected it to analysis. The mean of four analyses on the very small quantity available was as follows:—

	Per cent.
CaO	28·78
SiO_2	6·48
Na_2O	18·10
MgO	2·27
CO_2	31·41
SO_3	2·71
Cl	8·92
H_2O	1·45
Total	100·12

The solution gave a distinctly alkaline reaction.

There was some considerable variation in the amount of chloride, sulphate, and silica present. Roughly speaking, the analysis indicates the presence of about 50 per cent. of $CaCO_3$; 7 of $MgSO_4$; 14 of $NaCl$; and 18 per cent. of Na_2CO_3.

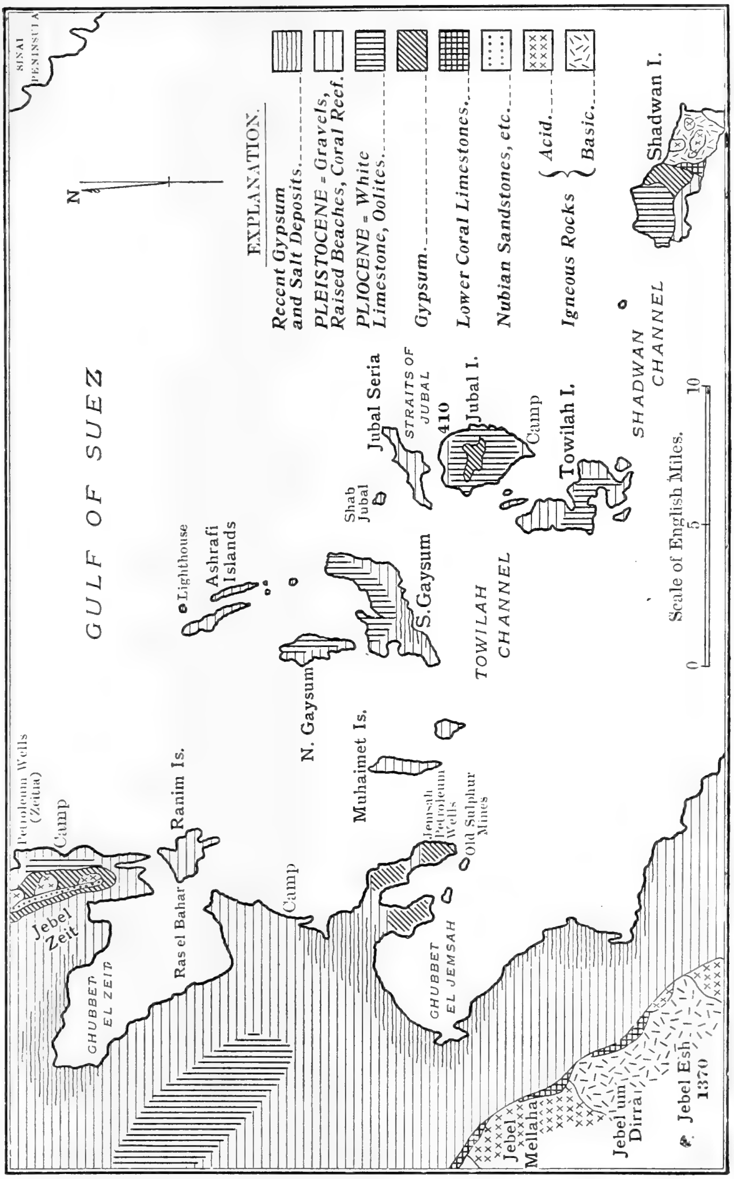
The presence of sodium carbonate is interesting, and suggests mass action between the salt and the limestone [1]:—

$$CaCo_3+2NaCl \rightleftharpoons CaCl_2+Na_2CO_3.$$

---

[1] C. M. Guldberg & P. Waage, 'Ueber die chemische Affinität' Journ. Prakt. Chem. vol. xix (1879) p. 69. Since the above was written, Mr. S. R. Illingworth has drawn my attention to the fact that Berthollet has shown that this reaction does take place on the shores of certain lakes in Egypt: see G. Senter, 'Outlines of Physical Chemistry' London, 1909, p. 139.

Fig. 4.—*Geological sketch-map of part of the Red Sea area.*



Calcium chloride was proved to be present in the limestone bearing the encrustations, and these were accompanied by the presence of fine transparent needles of very small size. The needles increased in quantity after specimens had been kept for a time, and were evidently a kind of efflorescence. They have low refractive index and bi-refringence, and give straight extinction. Analysis proved them to be the mineral epsomite ($MgSO_47H_2O$).

(*b*) Dealing now with the second type of gypsum and salt deposit, we are at once confronted with an attractive but somewhat difficult problem. An enormous series of gypsum and anhydrite deposits is present in the area which we are considering. They form beds hundreds of feet thick on the Jemsa peninsula, in the Zeit range, and elsewhere, localities not previously noted being the centre of Jubal Island and the northern end of Shadwan Island (see map, fig. 4, p. 255).

The beds of anhydrite are sometimes peculiar. The mineral occurs as a soft chalky-looking substance with a radiate structure. It looks as though the mineral had been formed from a bed of gypsum in which the crystals were present in radiating aggregates, resembling a spherulitic structure on a fairly large scale. An analysis of this anhydrite gave the following result:—

	Per cent.
CaO	38·70
MgO	2·08
SO_3	59·30
Na_2O and K_2O	trace
H_2O	0·12
Total	100·20

Barron & Hume[1] consider that these deposits represent 'gypsumized' limestones of the Eocene and Cretaceous formations. They are of opinion that the change has taken place from above, by the introduction of sulphuretted hydrogen due to the decay of organic matter in the raised-beach deposits with which these beds are often associated.

L. H. Mitchell,[2] on the other hand, connected the change with the igneous intrusions; and the close connexion between the beds of gypsum and the veins of sulphur formerly worked at Ras Jemsa would support his opinion. Moreover, hot water has been struck in two or three localities in course of the search for oil: this also could perhaps have played a part. Mitchell was of opinion that the granites of Jebel Zeit were intrusive into the overlying limestone series, but this is not confirmed by later studies of the locality.

---

[1] *Op. cit.* Egypt. Geol. Surv. Rep. 1902, pp. 192–97.

[2] 'Ras Gemsah & Gebel Zeit: Report on their Geology & Petroleum' [Egypt. Govt. Rep.] Cairo, 1887.

Now, although I have shown that the alteration of limestone to gypsum is proceeding at present in certain areas, there are many reasons for doubting the conclusions of the Survey geologists. In the first place, the gypseous series is of enormous thickness: reaching several hundreds of feet in the Zeit range, of almost pure white saccharoidal gypsum with beds of pale-blue anhydrite, and a variety which is pure white. The beds are in places both overlain and underlain by unaltered limestones, a fact which appears to be fatal both to the Survey theory and to Mitchell's older theory. The best evidence comes from recent borings.

Borings for oil throughout this region pass through a great series of beds consisting of gypsum, rock-salt, thin dolomitic limestones, and marls. At Jemsa and on Jubal Island the gypsum deposits are of great thickness, and the dolomitic beds are well developed; but the rock-salt is not so abundant. Borings to the north of these localities meet with converse conditions. The rock-salt with marly partings is most abundant, while the gypsum and dolomitic limestone are more rarely present as partings. It can be shown that there is some transition from one state of things to the other.

If we take the Ashrafi reef as centre and the southern extremity of the Jemsa peninsula as radius, and describe a circle, all borings near the centre of the circle pass through the rock-salt phase, while the borings on the rim of the circle pass through the gypsum-dolomite phase. At one or two horizons beach-deposits occur, with some sand and pebbly gravel: these suggest temporary encroachments of terrestrial conditions. This association and this distribution of beds seem to prove almost beyond doubt that the great gypseous series is an original deposit. The finding of fish-scales in the marly beds at the base of the gypsum series by Mr. J. Wells, and perfect fish-remains in marly partings higher in the series by Mr. C. Sara, sets the matter, however, beyond question.

The area in which the beds are found was evidently a land-locked basin that had no communication with the sea. The position of the salt-deposits with regard to the main gypsum-deposits is just what one would expect from a theoretical consideration of such conditions, and would not be likely to occur if the beds had originated by subsequent alteration.

Similar occurrences of salt, gypsum, and dolomite occur in many parts of America, chiefly in Texas and California. They have been fully dealt with by the geologists of the United States Survey.[1] Some of the gypsum of the Zeit range and elsewhere along the coast appears to be, in places, a secondary product derived from the principal beds by the action of rain and storm-waters, and re-formed on the plains. The wadis cutting through the gypseous series are invariably narrow and tortuous gorges with perpendicular walls. Where they debouch upon the plains there is a soft, white, ashy deposit,

---

[1] Bull. U.S. Geol. Surv. Nos. 213, 223, 225, 260, 285, 315, 364, etc.

stained brown or grey at the surface, and weathered into curious horny protuberances. This is called by American writers gypsite,[1] and is actually composed of an aggregate of crystalline plates of gypsum of microscopic size.

The remarkable effect of warm sea-water upon the gypsum was pointed out to me by Mr. Wells; and an experiment was carried out by Mr. Sara and myself, in order to obtain some idea of the solubility of the gypsum in such circumstances. Two masses of gypsum were treated:—

No. 1. A mass of 107 lbs. lost 52 lbs. in 5 days.
No. 2. " 117 " 37 " 3 "

The loss per day in both cases was approximately 10 per cent., a result which explains some physical features connected with the outcrops of the massive gypseous series.

The common association of petroleum, sulphur, gypsum, and rock-salt found in many parts of the world, as well as in the Red-Sea area, is critically discussed by G. I. Adams[2] in an able manner, though without very definite conclusions, since our knowledge of the facts is not yet sufficient.

The age of the gypseous series is difficult to determine, owing to the lack of fossils, though a few imperfect specimens have recently been found in the upper beds. The beds are seen to underlie white limestone of Pliocene or late Miocene age, especially on Jubal Island, where the junction is unconformable: a conglomerate marks the break. They rest upon beds of Eocene age at more than one locality in the Zeit and Um-Esh ranges. It thus appears that the gypseous series dates from some part of the Oligocene and Miocene Periods: it is certain that during that time continental conditions prevailed in Egypt.

Very few deposits which tend to bridge the gap between the Eocene and the Miocene have yet been discovered. Those of the Fayum in the Western Desert are well known, while these products of the evaporation of a salt-lake or series of salt-lakes which I have been describing may well be their contemporaries in the Eastern Desert. It is significant to note that the very similar gypsum-deposits which exist in Cyprus have also been assigned to the Oligocene Period.[3]

---

[1] F. L. Hess, 'A Reconnaissance of the Gypsum Deposits of California' Bull. U.S. Geol. Surv. 413 (1910) pp. 7 *et seqq.*

[2] Bull. U.S. Geol. Surv. 184 (1901) p. 49.

[3] C. V. Bellamy & A. J. Jukes-Browne, 'The Geology of Cyprus' Plymouth, 1905, pp. 22, 25.

XI. Comparisons.

The significance of these beds, both of salt and of gypsum, will not be lost upon the student of the Triassic rocks of Britain. The beds in the Red-Sea area are comparable in every way with those of the Keuper, although the great salt-masses in the Keuper are probably not comparable in thickness with those now described.

The coasts of the Red Sea are at present rising with what appears to be unusual rapidity, geologically speaking. If continued, this will entail a severance of the connexion with the Indian Ocean, and it seemed to me to be useful to endeavour to calculate the thickness of salt which would result from the desiccation that might ensue.

Taking the average depth of the Red Sea from the Admiralty Charts to be 2400 feet (probably a low estimate), the amount of salts dissolved in the sea as about 4 per cent., and their density 2·00,[1] I reckon that the thickness of such a bed of salt would be 50 feet. It would certainly be somewhat greater than this, because of certain obvious corrections that would need to be applied.

Now, this proves that the beds actually present could not have been formed by the desiccation of a sea having the salinity of the present Red Sea, unless that sea in the process of drying up shrank greatly in size and concentrated its salts over a limited area. Occasional additions of salt water by temporary inroads from the ocean will not explain matters, since such connexion with the ocean would in all probability have been accompanied by other phenomena, of which there is no evidence. Incursions of sea-water do seem to have occurred towards the end of the period, and are suggested by the alternating deposits of salt and gypsum, which appear to be somewhat late in age, and seem to occur only in the central parts of the area.

If we assume that the Keuper Sea was similar in depth to the Red Sea, we reach a similar conclusion, for beds of salt 100 feet thick are to be found in that formation. If, as seems more likely, we assume that the Keuper Sea was shallower, it is clear that its waters were vastly more saline than the waters of the present ocean. Now, since we have no reason to believe that the ocean was at any time much more saline than at present, it follows that the Keuper salt-beds were deposited in an inland sea unconnected with the ocean, since we know that where such seas are in continuous connexion with the ocean at the present day, there is little difference in the salinity.

There is, however, one strong contrast. Whereas, as Mr. A. R. Horwood has recently observed, there is a tendency for the higher beds to overlap the lower in Triassic times, a tendency due to general subsidence, the reverse is the case in the Red-Sea area. The lowest beds here tend to have the greatest extension, owing to the fact that this area is one that is rising. Hence the beds which would correspond with the Keuper Series occupy the smallest area, occurring in hollows in the older rocks.

---

[1] J. H. Howell, in J. B. Skertchley's 'Physical Geography' (31st ed.) 1896.

XII. Summary and Conclusion.

The results of the investigation are briefly as follows:—The 'gravels' of the Eastern Ranges are of local origin, accumulated by the sea under peculiar local conditions. The desert sands in the area are mostly derived from rocks in their immediate vicinity.

Dolomite rhombs are present in recent marly deposits formed under actual desert conditions.

Sand plays a part, apparently not hitherto observed, in the disintegration of rocks. It acts as innumerable wedges along joint-planes and cracks.

Recent calcareous deposits are converted into gypsum, with destruction of organic structures.

Sodium carbonate and epsomite are common as encrustations among the raised-beach and coral-reef deposits.

The age and distribution of the older salt and gypsum deposits are considered. It is suggested that the beds are contemporaneous with those of the Fayum, that is, are of Oligocene age. Close comparisons are possible in certain cases between the formations considered and those of the British Trias. The geology of the islands at the mouth of the Gulf of Suez is shown by means of a sketch-map (fig. 4, p. 255).

In conclusion, I have to acknowledge much valuable assistance from Mr. S. R. Illingworth in connexion with the chemical work done in preparation of this paper. To him my best thanks are due, as well as to my former pupil, Mr. Ewart Mather, who kindly made a check-analysis of the saline sand. Especially do I owe thanks to Prof. W. W. Watts, F.R.S., for much kindness both in reading through the paper and in making suggestions with regard to it.

EXPLANATION OF PLATES XIII–XVI.

Plate XIII.

Gully in the Um Esh range, showing the gap between the 'gravel'-terrace and the main hills. The head of the gully is filling with sand.

Plate XIV.

Fig. 1. View from the summit of a 'gravel'-terrace: the plain is seamed with radiating watercourses. In the distance are seen the salt-covered sands and the Gulf of Jemsa.

2. Limestone almost entirely fretted away by wind-blown sand, north of Jemsa.

Plate XV.

Fig. 1. Coarse sand with miniature dreikanter, from the plain between the Um Esh and the Jebel Zeit ranges. Natural size.

2. White limestone-cliffs on Jubal Island, illustrating the effect of wind-blown calcareous sand upon joint-planes. The projecting fossils show the dip of the strata.

A. W. Photo.

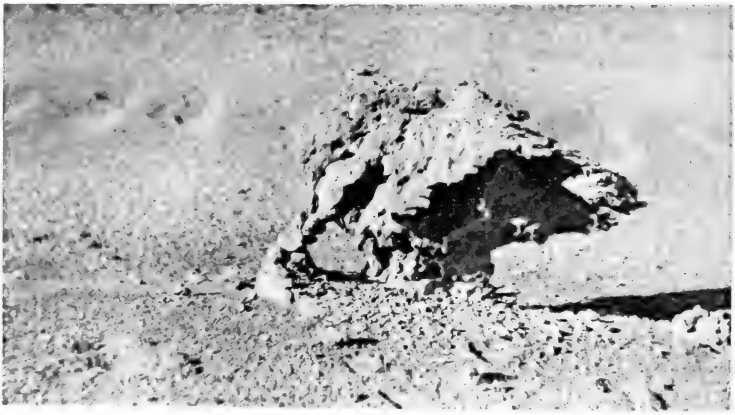
Bemrose Ltd., Collo., Derby.

VIEW OF GULLY IN THE UM ESH RANGE, SHOWING THE GAP BETWEEN THE GRAVEL-TERRACE AND THE MAIN HILLS AND SAND FILLING THE HEAD OF THE GULLY.

FIG. 1.—VIEW FROM THE SUMMIT OF A GRAVEL-TERRACE: THE GULF OF JEMSA IS SEEN IN THE DISTANCE.

A. W. Photo.

FIG. 2.—LIMESTONE ALMOST ENTIRELY FRETTED AWAY BY WIND-BLOWN SAND, NORTH OF JEMSA.



A. W. Photo.

Bemrose Ltd., Collo., Derby.

FIG. 1.—COARSE SAND WITH MINIATURE 'DREIKANTER,' FROM THE PLAIN BETWEEN THE UM ESH AND THE JEBEL ZEIT RANGES: NATURAL SIZE.

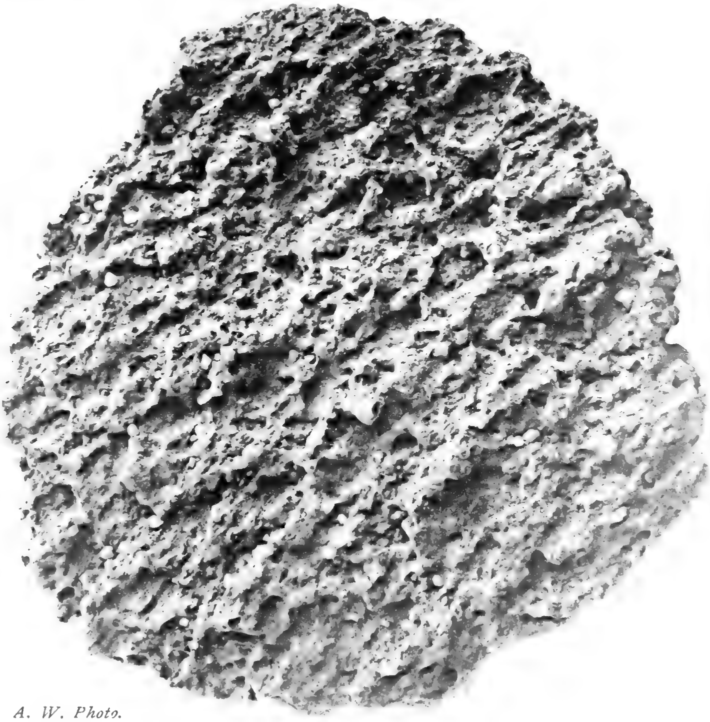
A. W. Photo.

FIG. 2.—WHITE LIMESTONE-CLIFFS, JUBAL ISLAND, SHOWING THE EFFECT OF WIND-BLOWN CALCAREOUS SAND UPON JOINT-PLANES.

A. W. Photo.

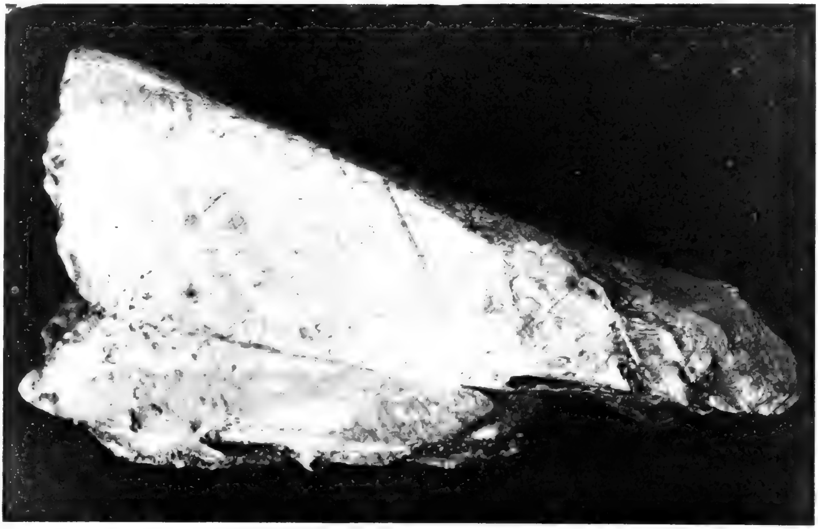
Bemrose Ltd., Collo., Derby.

FIG. 1.—BLOCK OF GRANITE FROM THE UM ESH RANGE, SHOWING THE FRETTING AWAY OF FELSPARS, THE OUTSTANDING QUARTZ, ETC.



A. W. Photo.

FIG. 2.—ARROWHEAD TWIN OF GYPSUM FROM JUBAL ISLAND, SHOWING THE MECHANICALLY ETCHED FIGURES.



A. W. Photo.

Bemrose Ltd., Collo., Derby.

PLATE XVI.

Fig. 1. Block of granite from the Um Esh range, showing the fretting-away of the felspar, the outstanding quartz, also the sand-grains driven into the softer material and lodged between the quartz-grains. (Two-thirds of the natural diameter.)

2. Arrowhead twin of gypsum from Jubal Island, showing the mechanically etched figures. (Four-fifths of the natural diameter.)

DISCUSSION.

Dr. C. G. **CULLIS** suggested a special determination of the crystal-rhombs described, in order to determine whether they were really dolomite, and not calcite.

Sir **THOMAS HOLLAND** supported the previous speaker's suggestion for a special check determination of the rhombohedral crystals of supposed dolomite. Beautifully sharp rhombs are found in the black mud of the Rajputana salt-lakes, but on chemical examination they prove to be calcite, not dolomite. Recent work in the Rajputana Desert reveals many features described by the Author, and long recognized as characteristic of the Triassic and other salt-bearing formations: among these are the plano-convex shape of the lenticular deposits; the contemporaneous formation of gypsum and dolomite with the salt; and the distribution of pebbles in an abundant sandy matrix, due to the action of sudden floods in desert regions. The work done by the speaker in conjunction with Dr. Christie (Rec. Geol. Surv. Ind. vol. xxxviii, 1909, p. 154) showed that the salt, of which over 54 million tons exist in Sambhar alone, is brought in in the form of fine dust from the coast of Cutch, some 500 miles away to the south-south-west. With the fine angular sand of the Bikaner Desert are found undamaged tests of foraminifera, which must have been carried bodily by the wind instead of being rolled with the heavier rounded sand-grains.

Dr. J. W. **EVANS** was glad to find that the Author employed the term dreikanter for the normal type of wind-worn stone with three approximately parallel edges, and not for the more special roughly tetrahedral form to which it was applied by some authors. He was much impressed by the evidence brought forward of the destruction of rocks by wind-action. He believed that many of the so-called 'plains of marine denudation' would prove to be the result of wind-erosion, and instanced that on which the Cambrian of the North-West of Scotland was deposited, as also the planed-down surface of the Palæozoic strata in South Wales and elsewhere, which was believed to date from the Triassic Period.

The **PRESIDENT** (Prof. **WATTS**) regretted that time did not permit of adequate discussion of the numerous and interesting points raised in the paper. The Author had spent a very considerable time on the ground and in working up his conclusions, and there could be no doubt that the paper constituted an important addition to the knowledge of desert conditions and deposits.

The **AUTHOR** thanked the President and the Fellows for the way

in which the paper had been received. He said that the presence of dolomite rhombs had first been suspected, as a result of analyses made of that portion of the marly sediments which was soluble in dilute acid. The rhombs were isolated by methods indicated by Dr. Cullis, and compared with his specimens; but the method of identification now described by him was not adopted. He was glad to hear of the distances to which salt was carried by the wind in Rajputana, since there was some indication of much the same phenomenon in the part of Egypt now described. Foraminifera were also carried to great distances, as in India; and the Author was surprised to find unbroken foraminifera in sands filling the gullies high up in the mountains. He agreed with Dr. Evans as to the important part played by wind in erosion. The planing-down effect of the wind was especially well seen on the islands in the Red Sea.

8. *On the* TEETH *of* PTYCHODUS *and their* DISTRIBUTION *in the* ENGLISH CHALK.

By GEORGE EDWARD DIBLEY, F.G.S. (Read March 8th, 1911.)

[PLATES XVII–XXII.]

Introductory Remarks.

AMONG the remains of fishes found in the Chalk, the teeth of *Ptychodus* are so conspicuous and so easily recognized by the quarrymen that they have long been collected in large numbers and distributed to various museums. Most of these fossils, however, bear no record of the exact locality or zone from which they were obtained, while groups of associated teeth have often been scattered without any note of the circumstances of their discovery. I have, therefore, devoted much attention during the past twenty years to the careful collecting of teeth of *Ptychodus* from the chalk-pits of the South-East of England, and I now propose to discuss their classification and the zonal range of the various species.

I have collected especially in the Gravesend, Rochester, and Medway-Valley area, where there are great excavations in a continuous series of Chalk-deposits, from the base of the zone of *Ammonites rhotomagensis* to the top of that of *Micraster coranguinum*. I have also obtained specimens from the Caterham Valley, Oxted, Merstham, and Betchworth; from Berkshire, Hampshire, Bedfordshire, and Cambridgeshire; and I have studied all the material in the British Museum, the Museum of Practical Geology (Jermyn Street), and the museums of Salisbury, Brighton, and Rochester. I have been particularly fortunate in discovering fifty sets of associated teeth, and have examined many more in the museums just enumerated.

The arrangement of the teeth of *Ptychodus* in the mouth is already known from specimens of *Pt. decurrens* found in the English Chalk,[1] and from others of *Pt. mortoni* found in the Chalk of Kansas (U.S.A.).[2] I have obtained confirmatory evidence of it in a naturally arranged group of teeth of *Pt. decurrens*, from the Lower Chalk of Wouldham near Rochester; and in another group of the same species given to me by Mr. G. Bishop, Manager of the Lime-Works at Merstham (Surrey).

It appears that the teeth are arranged in antero-posteriorly directed parallel rows, in symmetrical pairs on each side of a median row, which contains the largest teeth in one jaw (presumably the lower); while in the other (presumably the upper) the median row consists of diminutive teeth somewhat long and narrow, with the grooving of the enamel confined to the centre and across the width.

---

[1] A. Smith Woodward, Q. J. G. S. vol. xliii (1887) pp. 121–30; and *ibid.* vol. lx (1904) pp. 133–35.

[2] S. W. Williston, Kansas Univ. Geol. Surv. vol. vi (Palæont.) pt. ii (1900) pp. 234–40.

The rows diminish in size from the inner pair outwards. In *Pt. decurrens* there are not more than fifteen rows, while in *Pt. mortoni* there are seventeen rows of teeth. It is now, therefore, possible to interpret the numerous sets of associated though scattered teeth of other species, and to determine the variations which occur in different parts of the jaw.

I shall treat the several species in the order of their appearance in the English Chalk, and utilize the new material in defining them more exactly than earlier observers were able to do.

Description of the Fossil Teeth.

1. PTYCHODUS DECURRENS Agassiz. (Pl. XVII, fig. 2; Pl. XIX, figs. 20–24.)

1839. L. Agassiz, 'Poissons Fossiles,' vol. iii, p. 154 & pl. xxv *b*, figs. 1, 6, 7, 8, 21 (*non* figs. 2–5).

Specific characters.—Central part of crown of tooth not sharply raised, as a rule gently rounded or flattened. Transverse ridges small and numerous, extending to the lateral ridges and leaving space for a minimum of granulation; these ridges are sometimes bifurcating or intercalated, ending abruptly or curving sharply on reaching the margin, seldom showing a concentric arrangement; also rarely subdivided into tubercles. Numerous fine ridges extend at right angles to the transverse ridges, over the anterior and posterior portions of the tooth; this is a specially distinctive feature.

Variations.—The four naturally arranged sets of teeth already described by Dr. A. Smith Woodward differ much from each other, and illustrate well the difficulty of determining isolated teeth. In the first specimen[1] the fineness of the transverse ridges and grooves is noteworthy, and the crown in the lower median teeth is only slightly raised. In the second specimen (*op. cit.* fig. 2) the relatively great extent of the granulated marginal area is unusual, and the lateral teeth exhibit curious oblique distortion. In the third specimen (fig. 3), which belongs to the upper jaw, the small median teeth are peculiar in being nearly square, and the large teeth of the inner paired series have a remarkably raised crown.

In my own collection I have an associated set of eighty-four teeth from Wouldham which are identical with the foregoing, but the set possesses an additional feature in that it contains, among others of the lower jaw, one tooth of the median row which is characterized by an unusually elevated crown. This set contains seven teeth of the upper median row. These small median teeth may vary greatly, though similar in the individual, according to age. In Pl. XIX, fig. 20 represents a median tooth *in situ* belonging to this set. The other six median teeth are identical in shape and other features.

---

[1] Q. J. G. S. vol. xliii (1887) pl. x, fig. 1.

The dimensions in millimetres[1] of the principal teeth are as follows:—

	Length.	*Breadth.*
Small median tooth	8	6
Tooth from first inner paired row	14	12
Tooth from central row opposite dentition	14	12
Smallest lateral tooth	8	4

These teeth evidently belong to a young *Ptychodus.*

Pl. XIX, fig. 21 represents a median tooth (the only one preserved), belonging to an associated set of thirty-six teeth from Bluebell Hill, Burham. It is evident that this tooth is more elongated, though somewhat similar in shape; and, from comparison with the other teeth in the set, the suggestion arises that age accounts for the differences in shape, size, and development of the grooving.

The dimensions in millimetres are as follows:—

	Length.	*Breadth.*
Median tooth	11	8
Tooth of first inner paired row	27	21
Tooth of central row opposite dentition	32	23

Pl. XIX, fig. 23 represents the only preserved median tooth in another associated set of twenty-three teeth, also from Bluebell Hill.

The dimensions in millimetres are:—

	Length.	*Breadth.*
Median tooth	18	11
Tooth of first inner row, opposite dentition	30	20
Tooth of central row, opposite dentition	32	25

Pl. XIX, fig. 22 includes two median teeth united to inner paired rows by iron pyrites, and they belong to the set figured in Pl. XVII, fig. 1 *a.* They are 14 mm. long and 9 mm. broad.

Pl. XIX, fig. 24 represents one of two isolated teeth from Holborough, which evidently belonged to the largest form of *Pt. decurrens*; it is 21 mm. long and 12 mm. broad.

The fine Brighton specimen described and figured by Dr. A. Smith Woodward[2] may be regarded as a typical example of the species; and I have discovered a few median teeth of the upper jaw of the same form in the zone of *Holaster subglobosus* (Pl. XIX, fig. 22).

The foregoing sets belonged to individuals which possessed small teeth, the largest being only 14 mm. in length and 10 mm. in breadth, compared with others whose corresponding teeth are 51 mm. long and 36 mm. broad.

Besides these, there are still more marked varieties which have already received specific names, and I now proceed to describe them.

---

[1] Where measurements are given, the length is reckoned parallel to the grooving, and the width from the anterior to the posterior portion of the tooth, except in the case of the small median teeth, in which case they are reversed.

[2] Q. J. G. S. vol. xliii (1887) pl. x, fig. 2.

PTYCHODUS DECURRENS, var. DEPRESSUS (Dixon). (Pl. XVII, figs. 1 *a* & 1 *b*.)

Though described as belonging to a distinct species, *Pt. depressus*, by Dixon,[1] the teeth of this form only differ from those typical of *Pt. decurrens* in being somewhat more flattened and depressed. They are common in the zone of *Holaster subglobosus*, and I have found interesting associated sets in the pit at Bluebell Hill, Burham (B.M. P 10255), and in Peter's Pit, Wouldham (B.M. P 10336). The latter specimen comprises fifty teeth, of which thirty-two occur still in their natural arrangement, showing a small portion of the dentition of the upper jaw (Pl. XVII, fig. 1 *a*). From front to back this dentition is very convex, and the teeth do not appreciably increase in size backwards. The usual median row of small teeth is partly obscured by the crushing together of the large teeth of the inner paired series.

PTYCHODUS DECURRENS, var. OWENI (Dixon). (Pl. XVIII, figs. 1–11 & Pl. XIX, fig. 8.)

The teeth described as *Pt. oweni* by Dixon[2] have not hitherto been found in their natural arrangement; but I have selected the isolated specimens shown in Pl. XVIII, figs. 1–11, to prove that there is every gradation between them and the normal teeth of *Pt. decurrens*. Indeed, it seems probable that the peculiarly irregular and broken ridges that characterize *Pt. oweni* occur chiefly on the principal median teeth; for in one set, which evidently belongs to a single individual (B.M. 39137–38), many of the larger teeth correspond exactly with those described as *Pt. oweni*, while several of the smaller lateral teeth are typically those of *Pt. decurrens*. I have also observed the same variability of the ridging on the teeth in other associated sets.

The type tooth and three other specimens in the Bowerbank Collection are labelled as having been obtained from Snodland,[3] Rochester. I have found two similar teeth from this locality, where only the Lower Chalk was worked at the time.

From Oxted I obtained, quite recently, an associated set of fourteen teeth of *Pt. decurrens* which proved to be worthy of note. Three of the central teeth of the lower dentition are of an extraordinary size, the largest being 51 mm. in length and 42 mm. in breadth (Pl. XIX, figs. 1–3). The grooving on the posterior half is of the typical form, while the next four or five adjoining rows are sharply curved towards the anterior portion, their ends being sharply recurved and extending to the front edge of the tooth. Nearly the whole of the anterior half is occupied by numerous secondary grooves radiating from the centre, and thus partakes of the features belonging to the variety *oweni*. Of the remaining teeth, there are

---

[1] 'Geology of Sussex' 1850, p. 363 & pl. xxxi, fig. 9.

[2] *Ibid.* p. 364 & pl. xxxi, fig. 2.

[3] Halling is the proper locality, Snodland being situated on the Gault.

seven large teeth belonging to the lateral rows, of which six are much deformed as regards shape; two are shown in Pl. XIX, figs. 4 & 5. The grooving also is very abnormal in many of the teeth.

There is a set in the British Museum (Bowerbank Collection, 39138) from Wouldham, and another which is labelled as coming from Halling, though it evidently belongs to the previous set: as can be seen from the matrix, the peculiar staining, and the abnormality in shape and grooving resembling the Oxted set, but with an additional feature in the form of small papillæ developed in the grooves (Pl. XVIII, fig. 4 & Pl. XIX, fig. 15).

PTYCHODUS DECURRENS, var. MULTISTRIATUS (A. S. Woodward).
(Pl. XVIII, figs. 12 & 13; Pl. XIX, figs. 6, 10, 12, & 14.)

The so-called *Pt. multistriatus* (A. S. W.)[1] from the zone of *Holaster subglobosus* comprises large teeth marked with numerous fine ridges, which are sharply recurved into a concentric arrangement. I am now able to prove, however, that these are merely from the inner rows of a dentition in which the outer teeth conform to the typical *Pt. decurrens* plan: for, in 1905, I obtained from the same zone at Holborough, near Rochester, an associated set of seventeen teeth, of which only those of the large median lower row are typical examples of the so-called *Pt. multistriatus*; while those of at least six paired rows exhibit every gradation between this condition and that of the true *decurrens*-ridging, which characterizes the outermost rows. Some of these gradations may even be seen in the type-specimen in the British Museum (P 2681).

PTYCHODUS DECURRENS, var. LÆVIS (A. S. Woodward).

The very small and remarkably smooth teeth from the Lower Chalk, described as *Pt. lævis* (A. S. Woodward)[2], exhibit the characteristic grooving of *Pt. decurrens*, and can only be regarded as a dwarfish variety. I have observed a similar abnormal smoothness in a tooth of *Pt. mammillaris* in my own collection. Several examples are now known; and I have obtained them from the zone of *Holaster subglobosus*, both at Betchworth and at Burham.

Geological Range.

Ptychodus decurrens occurs chiefly in the zone of *Holaster subglobosus*. It is also found, but rarely, in the *Actinocamax-plenus* Marls, and still more rarely in the base of the zone of *Rhynchonella cuvieri*. It has not hitherto been discovered at any higher horizon. Two teeth of this species are in the Museum of Practical Geology (Jermyn Street), and are said to have been obtained from the

---

[1] Catal. Fossil Fishes Brit. Mus. pt. i (1889) p. 146 & pl. v, figs. 4–6.

[2] Proc. Geol. Assoc. vol. xiii (1893–95) p. 192 & pl. v, figs. 5–6.

Upper Greensand. I have not yet obtained a specimen from the zone of *Ammonites rhotomagensis*.[1]

It is interesting to note that *Pt. decurrens* is the only species from the English Chalk of which the teeth have been found in their natural arrangement.

2. PTYCHODUS POLYGYRUS Agassiz. (Pl. XX, figs. 1 & 2; Pl. XXI, figs. 1 & 2.)

1839. L. Agassiz, 'Poissons Fossiles' vol. iii, p. 156, pl. xxv, figs. 10–11 & pl. xxv *b*, fig. 23.

Specific characters.—Central part of crown of tooth flattened. Transverse ridges relatively large, curving round more or less at the lateral ends, sometimes forming gyrations; marginal granulated area usually of considerable extent, coarsely marked, never impressed with radiating grooves.

Variations.—The teeth referred to this species are remarkably varied, and Agassiz divided them into four groups to which he gave provisional names. My studies of numerous associated sets of teeth prove that there are gradations between the extreme types, and I therefore continue to regard the different forms merely as varieties.

In the typical *Pt. polygyrus*, as defined by Agassiz, the principal teeth are much flattened, the grooving is very coarse, with frequent gyrations, and the marginal granulation is only wide in some of the large teeth of the lower median row. One of these lower median teeth is figured by Agassiz[2] under the name of *Pt. latissimus*. The finest known specimen, showing the greater part of the dentition of both jaws, was obtained by Mr. W. Murton Holmes from the zone of *Micraster cor-anguinum* at Banstead (Surrey), and is now in the British Museum (P 10771). It comprises about 150 scattered teeth, which I have been able to arrange approximately in their natural order. Besides those of the median series, there are also teeth of five or six paired rows in each jaw, and a selection is shown in Pl. XXI, figs. 1 & 2.

An associated set of about twenty similar teeth has been discovered by Mr. C. Gosling, in the same zone of the Chalk, at Croydon; and it may be added that there is another set in the British Museum (P 4551) from the Chalk of Normandy.

The form just described appears to be characteristic of the *Micraster cor-anguinum* Zone.

---

[1] [After this paper had been read, Mr. E. T. Newton kindly told me that there was a tooth of *Ptychodus* among a collection of fossils from the Potton Beds of the Lower Greensand, at the Museum of Practical Geology, Jermyn Street. I have now seen this specimen, which is iron-stained just as are the other fossils from this horizon: it is undoubtedly a tooth of *Pt. decurrens* var. *depressus*. It was unrecorded by Mr. Keeping in 'The Fossils & Palæontological Affinities of the Neocomian Deposits of Upware & Brickhill' Cambridge, 1883. I consider it to be a derived fossil.—*G. E. D., March 22nd, 1911.*]

[2] *Op. cit.* pl. xxv *a*, fig. 8.

PTYCHODUS POLYGYRUS, var. CONCENTRICUS (Agassiz).

This name was given by Agassiz[1] to an imperfect tooth from the Upper Cretaceous of Quedlinburg, characterized by a rather high crown, well-marked concentric ridges in the median part, and a wide margin of fine granulation. I have not found any exactly similar teeth in the English Chalk; but one which very nearly approaches it, from the *Holaster-subglobosus* Zone at Bluebell Hill, I consider to be one of the abnormal forms of *Pt. decurrens* (Pl. XIX, fig. 18).

PTYCHODUS POLYGYRUS, var. MARGINALIS (Agassiz). (Pl. XXI, figs. 4 *a*–4 *c*.)

As defined by Agassiz,[2] the teeth of this form have a flattened raised median part, crossed by numerous ridges, which are only sometimes concentric, and bounded by a wide coarsely granulated area. I have only met with one tooth (Pl. XXI, fig. 4 *a*) from Halling and an associated set of fifteen teeth from Bluebell Hill (zone of *Terebratulina gracilis*) which well illustrate the foregoing features; two teeth belonging to this set are figured with the previous example (figs. 4 *b* & 4 *c*). They tend to connect *Pt. polygyrus* with *Pt. mammillaris*.

Teeth of *Ptychodus polygyrus* are commonest in the zones of *Rhynchonella cuvieri* and *Terebratulina gracilis*.

An associated set of about fifty teeth of this variety from Beachy Head (B.M. P 6141) is marked by parallel grooves with only slightly curved ends; and there are also similar sets in the British Museum from Halling and Bluebell Hill (36747, 47907). I have also sets from Burham and Wouldham which agree with those just mentioned (Pl. XXII, fig. 2). In some cases, however, the teeth are fairly flat and the grooves on the teeth are finer, more numerous, and often concentric, at least in the principal rows; and I have obtained instructive examples from Tingey's Pit, Wouldham. In one associated series of a hundred and thirty teeth (B.M. P 10464), which contains six of the small median teeth, I have been able to arrange and identify most of the rows of both jaws. Three teeth from the (hypothetical) upper set are shown (Pl. XXII, fig. 1).

An associated set of seventeen teeth from the zone of *Actinocamax quadratus* of Northern France described by M. Leriche[3] is of much interest, as showing a gradation between *Pt. polygyrus* and *Pt. latissimus*. Nearly similar are some teeth from Wantage, preserved in the Museum of Practical Geology.

An interesting variety is shown in Pl. XXI, fig. 3, which consists of five teeth selected from an associated set containing twenty-two

---

[1] 'Poissons Fossiles' vol. iii (1833–45) p. 156 & pl. xxv *b*, fig. 22.

[2] *Ibid.* p. 157 & pl. xxv, figs. 4–8.

[3] 'Révision de la Faune ichthyologique des Terrains crétacés du Nord de la France' Ann. Soc. Géol. Nord, vol. xxxi (1902) p. 99 & pl. ii, fig. 23.

teeth from Dunton Green (probably the top of the *Rhynchonella-cuvieri* Zone). These teeth are very flat, and possess a finely granulated margin, which is very broad on the small lateral teeth.

Ptychodus polygyrus, var. sulcatus (Agassiz).

The teeth thus named[1] are essentially intermediate between *Pt. polygyrus* and *Pt. decurrens.* Until similar specimens are discovered in an associated set, it is impossible to decide which species they represent.

Geological Range.

The typical teeth of *Pt. polygyrus* are found exclusively in the zone of *Micraster cor-anguinum.* The species ranges from the zone of *Rhynchonella cuvieri* upwards to that of *M. cor-anguinum,* where it is rare, and afterwards disappears.

Teeth of the typical form, from the Niobrara Chalk of Kansas (U.S.A.), have also been described under the name of *Pt. martini* by Prof. Williston.[2]

3. Ptychodus latissimus Agassiz. (Pl. XX, figs. 3–5.)

1839. L. Agassiz, 'Poissons Fossiles' vol. iii, p. 157, pl. xxv *a* & pl. xxv *b*, figs. 24–26.

Specific characters.—Central part of crown of tooth flattened. Transverse ridges very large and few, four or five in the big median teeth, two or three in the small lateral teeth; slightly curved at the ends. The coarse marginal granulation laterally tends to continue the transverse ridges, and is anteriorly arranged in more or less distinct radiating lines.

Observations.—This species is well marked, and the teeth referred to it are less variable than those of other species. I have obtained an associated series of thirty-six teeth from the zone of *Holaster planus* at Bluebell Hill, Burham (Pl. XX, fig. 3), and there is another series (artificially arranged on a block of chalk) in the Willett Collection, Brighton Museum.

Geological range.—Most of the teeth of this species have hitherto been found isolated, and I have only met with them in the zones of *Terebratulina gracilis* and *Holaster planus* in Kent and Surrey.

4. Ptychodus dixoni, sp. nov. (Pl. XX, figs. 1 & 2.)

1850. *Pt. latissimus,* Dixon (*non* Agassiz), 'Geology of Sussex' p. 362 & pl. xxx, figs. 1 & 2. [Fig. 2 is *Pt. polygyrus* (Ag.), high zonal form.]

The tooth figured by Dixon as *Pt. latissimus* differs from other known species; it does not agree with Agassiz's type, which is shown in fig. 3, and to which Dixon gave the name of *Pt. pauci-sulcatus,* evidently in error.

---

[1] *Op. cit.* p. 156, pl. xxv, fig. 9 & pl. xxv *b*, fig. 21.

[2] Univ. Geol. Surv. Kansas, vol. vi (Palæontology) pt. ii (1900) p. 240.

In 1898 I discovered in the *Terebratulina-gracilis* Chalk at Whyteleafe a tooth which I failed to recognize; subsequent discoveries of an associated set of thirty-six teeth in the same zone at Cuxton, in which the features exhibited by the Whyteleafe tooth were persistent throughout the set (Pl. XX, fig. 1), and of another associated set of fourteen teeth from the same locality, have confirmed my reasons, with which Dr. A. S. Woodward agrees, for treating this as a new species.

Specific characters.—Shape: lateral teeth more oblong than in the previously described species; central teeth of large inner paired row of (presumably) upper dentition nearly square. Grooving not nearly so coarse as in *Pt. latissimus*, but more so than in *Pt. polygyrus*, with a tendency to occupy the whole surface of the lateral teeth and a curving of the ends towards the anterior portion of the tooth, as in *Pt. latissimus*. The granulated area is less than in *Pt. latissimus* and *Pt. polygyrus* var. *marginalis*, notably in the anterior portion of the lateral teeth, while in the big central teeth the granules are very coarse where they adjoin the last groove; this area is somewhat increased in these large teeth.

The evidence from which these features were obtained is (1) the tooth already mentioned; (2) the associated set (B.M. P 10260); (3) an associated set of eleven large teeth—in all probability from the first inner paired rows of the upper dentition,—and three smaller teeth belonging to the same set from the *Terebratulina-gracilis* Zone at Cuxton and kindly lent by Mr. J. G. Wilson for comparison with the other examples: one of these large teeth is shown of the natural size in Pl. XX, fig. 2; (4) a tooth recently obtained from the same locality; (5) an associated set from Lewes (B.M. 4355); and (6) an associated set, Dixon Collection (B.M. 28339).

Geological range.—This species has been so far recorded only from the zone of *Terebratulina gracilis*, and probably from that of *Holaster planus*.

5. Ptychodus mammillaris Agassiz. (Pl. XXII, figs. 3–5.)

1839. L. Agassiz, 'Poissons Fossiles' vol. iii, p. 151 & pl. xxv *b*, figs. 12–20 (*non* 11).

1850. *Ptychodus latissimus* F. Dixon, 'Geology of Sussex' pl. xxxi, fig. 3 (*errore*).

Specific characters.—Central part of crown of tooth sharply raised. Transverse ridges numerous, extending directly across the raised part and continued down its sides, sometimes tending to become gyrate at the ends. Granulated marginal part of the tooth very wide, fine, usually crossed by a few shallow radiating channels; granules tending towards a concentric arrangement. Lateral teeth very unsymmetrical (Pl. XXII, fig. 4).

Remarks.—The four type-specimens in the Mantell Collection are isolated teeth with remarkably flattened crowns. Others are more rounded at the summit of the raised portion. Many specimens exhibit some approach to the teeth of *Pt. polygyrus*, but they can always be distinguished by the character of the marginal

granulated area. In one associated set of six teeth (B.M. 4362) some of the transverse ridges are irregularly subdivided, as in *Pt. decurrens* var. *oweni* (Pl. XVIII, fig. 3).

Geological range.—This species ranges through the zones of *Rhynchonella cuvieri*, *Terebratulina gracilis*, and *Holaster planus*, and may also occur in that of *Micraster cor-testitudinarium*. A variety from the base of the *Rhynchonella-cuvieri* Zone at Burham and Betchworth is characterized by an unusually fine marginal granulation, in which the radiating grooves are scarcely noticeable or are entirely absent (Pl. XXII, fig. 5).

6. PTYCHODUS RUGOSUS Dixon. (Pl. XXII, figs. 6 *a* & 6 *b*.)

1850. F. Dixon, 'Geology of Sussex' p. 362 & pl. xxxi, fig. 5.

Specific characters.—Teeth resembling those of *Pt. mammillaris*, but remarkably smooth; both the transverse grooving and the marginal granulation are feebly marked; the grooves are fewer than in *Pt. mammillaris.*

Remarks.—The crowns of the typical teeth are rounded, and there is often a characteristic puckering. When they are more flattened and begin to show some distinct surface-markings, they approach the teeth of *Pt. mammillaris.* In an associated set in the British Museum (P 5335), and in another set in my own collection, the typical teeth occur together with smaller teeth which have an excessively elevated crown and smooth sides. These smaller teeth were erroneously named *Pt. altior* by Dixon.[1]

Geological range.—*Pt. rugosus* seems to appear first in the zone of *Micraster cor-testitudinarium*, and has not been found above that of *M. cor-anguinum*. I have obtained teeth from the Haling Pit (Purley), Strood, and Gillingham. In the British Museum (Natural History) there are also specimens from Purley Junction Pit (now disused) and Northfleet. Teeth of the same form, from the Niobrara Chalk of the Western States of North America, were named *Pt. whipplei* by J. Marcou.[2]

7. PTYCHODUS MORTONI Agassiz. (Pl. XXII, figs. 7 & 8.)

1839. L. Agassiz, 'Poissons Fossiles' vol. iii, p. 158 & pl. xxv, figs. 1–3.

Specific characters.—Central part of crown of teeth raised to a point, from which grooves and ridges radiate irregularly; marginal area wide, and finely granulated.

Remarks.—Although common in the Cretaceous of North America,[3] whence the type-specimen was obtained, this form of tooth is extremely rare in the English Chalk.

Dixon[4] figures a specimen from Shoreham, and Dr. A. S. Woodward[5] another from Winchester; apparently the crown alone of

---

[1] 'Geology of Sussex' 1850, p. 362 & pl. xxx, fig. 10.

[2] 'Geology of North America' Zürich 1858, p. 33.

[3] S. W. Williston, Kansas Univ. Geol. Surv. vol. vi (Palæont.) pt. ii (1900) pp. 234–40.

[4] 'Geology of Sussex' 1850, p. 364 & pl. xxxi, figs. 6–7.

[5] Proc. Geol. Assoc. vol. xiii (1893–95) p. 191 & pl. v, fig. 4.

this tooth has been preserved (Pl. XXII, fig. 8). I have not been fortunate enough to discover any examples.

The range of the English species of *Ptychodus* is summarized in the following synopsis :—

NAMES OF SPECIES AND VARIETIES.	Upper Greensand.	Chalk Marl.	Zone of *Holaster subglobosus.*	Zone of *Actinocamax plenus.*	Zone of *Rhynchonella cuvieri.*	Zone of *Terebratulina gracilis.*	Zone of *Holaster planus.*	Zone of *Micraster cor-testitudinarium.*	Zone of *M. cor-anguinum.*	
Ptychodus decurrens	–	–	—	—						
,, var. *multistriatus* ...			—							
,, var. *oweni*			—							
,, var. *depressus*			—							
Pt. polygyrus					—	—	—	—	—	
Pt. latissimus						—	—	—		
Pt. dixoni						—	—			
Pt. mammillaris					—	—	—	—		
Pt. rugosus								—	—	
Pt. mortoni										— ?

Concluding Remarks.

In concluding these observations on the genus *Ptychodus*, it is my pleasant duty to offer my sincere thanks to many friends for their assistance during the compilation of the foregoing facts. Among these I may mention Mr. H. A. Allen, Dr. H. P. Blackmore, Mr. C. Gosling, Mr. W. Murton Holmes, Dr. F. L. Kitchin, Mr. E. T. Newton, Mr. R. B. Newton, Dr. A. W. Rowe, Mr. C. Davies Sherborn, Dr. Ivor Thomas, Mr. Toms (of Brighton), Mr. Henry Woods, Mr. George Payne (of Rochester), and Mr. R. M. Brydone. I am also greatly indebted to Mr. Eustace Large for many photographs and lantern-slides during the earlier period of the preparation of this paper, and recently to Mr. Philip Dollman, to whom I am especially indebted for his unceasing interest in connexion with the majority of the lantern-slides, photographs,

and enlargements necessary for the elucidation of the subject. Finally, I wish especially to offer my warmest thanks to Dr. A. Smith Woodward, who has not only been my constant friend and adviser throughout the preparation of this paper, but has always inspired and fostered my energies towards unravelling the zonal history of the Fishes of the English Chalk.

EXPLANATION OF PLATES XVII–XXII.

PLATE XVII.

Fig. 1 *a*. An associated set of teeth of *Ptychodus decurrens* (Ag.) var. *depressus* of Dixon; from the zone of *Holaster subglobosus*, Burham, near Rochester, found *in situ*. The lower portion illustrates the curvature of the palate, the whole series belonging to the upper dentition.

Fig. 1 *b*. A detached portion of the above set containing three small median teeth; this group is cemented by pyrite, and is of the natural size. (B.M. P 10336, G. E. Dibley Coll.)

Fig. 2. An associated set of *Ptychodus decurrens* (Ag.), found *in situ* and representing part of the lower dentition; from the zone of *Holaster subglobosus*, Merstham (Surrey). Slightly less than natural size. (G. E. Dibley Coll.)

PLATE XVIII.

Figs. 1–11. A series of teeth preserved in the British Museum (Natural History), hitherto named *Ptychodus oweni* (Dixon): to show that they merely represent a phase of extreme variation of *Pt. decurrens*. (Compare figs. 3, 5, & 8 with figs. 1, 2, 3, & 17 of Pl. XIX.) Three-eighths of the natural size.

Figs. 12 & 13. Part of an associated set of teeth of *Ptychodus decurrens*, arranged hypothetically to represent (12) part of the upper dentition and (13) part of the lower dentition. This set also illustrates extreme variation; the big central teeth were known formerly as *Pt. multistriatus* (A. S. Woodward). Half of the natural size.

PLATE XIX.

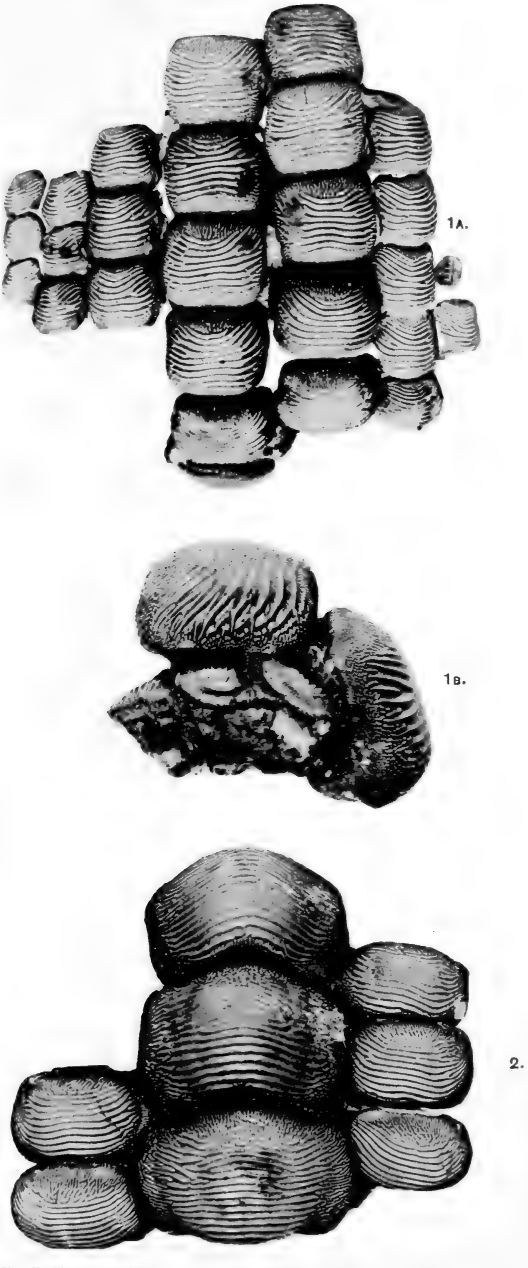
Figs. 1–3. Three teeth of *Ptychodus decurrens* (part of an associated set) belonging to the central row of the lower dentition, and illustrating abnormal development of the enamel (figs. 4 & 5 also belong to the same individual, and illustrate malformation). Half of the natural size. From the zone of *Holaster subglobosus*, Oxted (Surrey). The largest tooth is 5·7 centimetres long and 5 cms. broad. (G. E. Dibley Coll.)

Figs. 4–19. A series of teeth of *Ptychodus decurrens*, arranged to show marked variation of the species. From the zone of *Holaster subglobosus* of various localities. Half of the natural size. (G. E. Dibley Coll.)

Figs. 20–24. Median teeth of the upper dentition of *Ptychodus decurrens* belonging to five individuals, and arranged according to age (see p. 265 in regard to dimensions). No. 22 belongs to the set shown in Pl. XVII (B.M. P 10336, G. E. Dibley Coll.).

Fig. 25. Posterior aspect of a tooth of *Ptychodus decurrens*, showing the fine grooves developed at right angles to the crown and continuous to the root, a great characteristic of this species; from the zone of *Rhynchonella cuvieri*, Betchworth (Surrey). (G. E. Dibley Coll.)

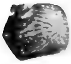
Fig. 26. Terminal tooth of one of the lateral rows of a small *Ptychodus decurrens* bordering the anterior portion of the palate, belonging to an associated set from the zone of *Holaster subglobosus*, Wouldham, near Rochester. Very slightly enlarged. (G. E. Dibley Coll.)



Philip Dollman, Photo. *Bemrose Ltd., Collo., Derby.*

TEETH OF PTYCHODUS DECURRENS.

1.

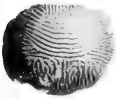


2.

3.

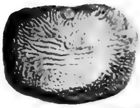
4.

5.

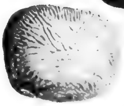


6.

7.

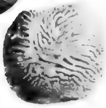


8.

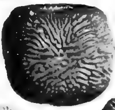


9.

10.



11.

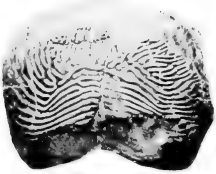


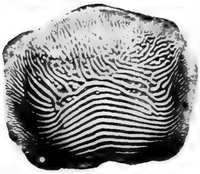
12.

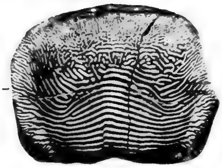
13.

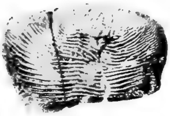
Philip Dollman, Photo. *Bemrose Ltd., Collo., Derby.*

TEETH OF PTYCHODUS DECURRENS.

1.


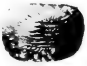
2.


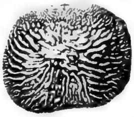
3.


4.


5.


6.


7.


8.


9.

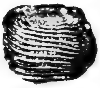

10.


11.


12.


13.

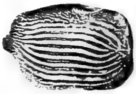

14.

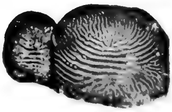

15.


16.

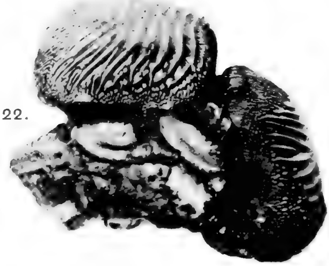

17.


18.


19.


20.


21.


22.


23.


24.

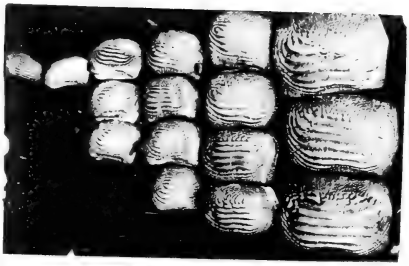

25.


26.

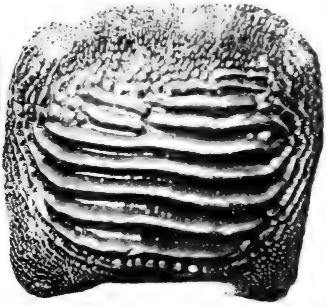

Philip Dollman, Photo. *Bemrose Ltd., Collo., Derby.*

TEETH OF PTYCHODUS DECURRENS.

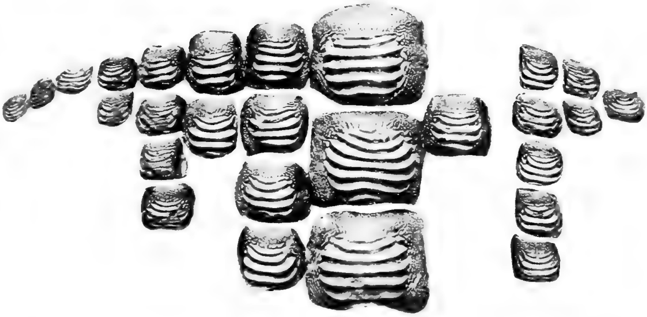
1.



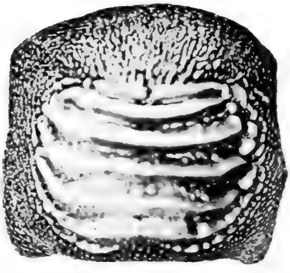
2.



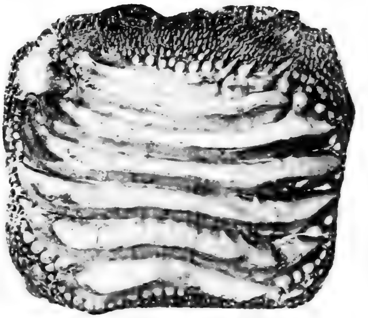
3.



4.



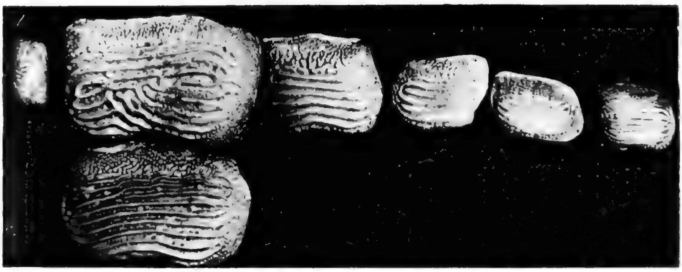
5.



Philip Dollman, Photo.

Bemrose Ltd., Collo., Derby.

TEETH OF PTYCHODUS DIXONI & PT. LATISSIMUS.

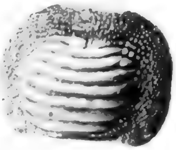


1.

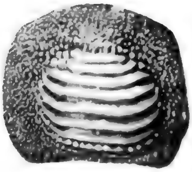
2.

3.

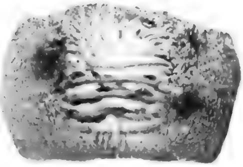
4c.



4b.



4a.



Philip Dollman, Photo.

Bemrose Ltd., Collo., Derby.

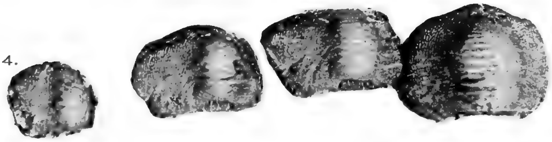
TEETH OF PTYCHODUS POLYGYRUS.

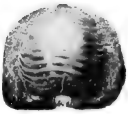
1.

2.

3.

4.





5.

6A.

6B.

7.

8.

9.

Philip Dollman, Photo. *Bemrose Ltd., Collo., Derby.*

TEETH OF PTYCHODUS POLYGYRUS, PT. MAMMILLARIS, PT. RUGOSUS, & PT. MORTONI.

PLATE XX.

Fig. 1. Part of an associated set of teeth, arranged to show a portion of the upper dentition of *Ptychodus dixoni*, sp. nov.; from the zone of *Terebratulina gracilis*, Cuxton, near Rochester. Slightly more than two-thirds of the natural size. (B.M. P 10260, G. E. Dibley Coll.)

Fig. 2. Large tooth of *Ptychodus dixoni* belonging to the lower dentition. (This tooth forms part of an associated set of fourteen teeth, the majority comprising the large teeth of this dentition.) Natural size. In the possession of Mr. J. G. Wilson, Cuxton.

Fig. 3. Part of an associated set of teeth of *Ptychodus latissimus* Ag., arranged to illustrate part of the lower dentition. From the zone of *Holaster planus*, Bluebell Hill, Burham, near Rochester. (G. E. Dibley Coll.)

Fig. 4. A tooth from the central row of the above. Natural size.

Fig. 5. A tooth from the central paired row of opposite dentition, and belonging to the same set. Natural size.

PLATE XXI.

Fig. 1. Part of an associated set of teeth of *Ptychodus polygyrus* Ag., high zonal form, arranged to illustrate part of the upper dentition.

Fig. 2. Part of the same set, to illustrate the lower dentition. Note the variation in development of the grooving of the enamel. The biggest tooth of the central row shown in this figure measures 7 centimetres in length and 6·5 cms. from back to front. From the zone of *Micraster cor-anguinum*, Banstead (Surrey). (B.M. P 10771.)

Fig. 3. Part of an associated set of teeth of *Ptychodus polygyrus* Ag., low zonal form, nearly flat and showing broad marginal granulation. Zone of *Rhynchonella cuvieri* (upper portion), Dunton Green. The largest tooth is 5·5 centimetres long and 4 cms. broad. (G. E. Dibley Coll.) Half of the natural size.

Fig. 4. Three teeth of *Ptychodus polygyrus* var. *marginalis* (Ag.). The biggest tooth is slightly less than natural size. and is from the zone of *Terebratulina gracilis*, Halling, near Rochester. The two smaller belong to an associated set of teeth from the same zone, Bluebell Hill, near Rochester. (G. E. Dibley Coll.)

PLATE XXII.

Fig. 1. Three teeth belonging to an associated set of 129 of *Ptychodus polygyrus* Ag., having a flat surface and the grooving gyrate. From the zone of *Terebratulina gracilis*, Wouldham, near Rochester. Slightly less than natural size. (B.M. P 10464, G. E. Dibley Coll.)

Fig. 2. Part of an associated set of teeth of *Ptychodus polygyrus*, Ag., with the grooving nearly parallel. From the zone of *Terebratulina gracilis*, Bluebell Hill, Burham. (G. E. Dibley Coll.) Five-eighths of the natural size.

Fig. 3. Part of an associated set of teeth of *Ptychodus mammillaris* Ag., from the zone of *Terebratulina gracilis*, Cuxton, near Rochester. Half of the natural size. (G. E. Dibley Coll.)

Fig. 4. Part of an associated set of teeth of *Ptychodus mammillaris* belonging to the edge of the palate. Zone of *Holaster planus*, Cuxton. Slightly more than half of the natural size.

Fig. 5. Tooth of *Ptychodus mammillaris* Ag., low zonal form. Zone of *Rhynchonella cuvieri*, Betchworth (Surrey). Two-thirds of the natural size.

Figs. 6 *a* & 6 *b*. Part of an associated set of teeth of *Ptychodus rugosus* Dixon. Zone of *Micraster cor-testitudinarium*, Purley. The terminal tooth of the above set is enlarged to nearly three-quarters of the natural size (fig. 6 *b*), and is from the base of the *Micraster cor-anguinum* Zone, Chatham. (G. E. Dibley Coll.)

Fig. 7. Lateral end tooth of *Ptychodus mortoni* Ag., from Kansas (U.S.A.). Slightly less than the natural size.

Fig. 8. Tooth of *Ptychodus mortoni* Ag., in the Oxford University Museum, from the Chalk near Winchester. (Photograph from drawing in Proc. Geol. Assoc. vol. xiii, 1893–95, pl. v, fig. 4.)

Fig. 9. Terminal tooth of *Ptychodus polygyrus* Ag., belonging to the set shown in fig. 3 of Pl. XXI. Natural size.

Discussion.

Mr. E. T. Newton said that he was glad of the opportunity of testifying to the great value of the palæontological work which the Author had been carrying on for a number of years, and was gratified to think that at length an important piece of it was likely to be published. Although *Ptychodus* teeth from the Chalk were so commonly to be seen in collections of fossils, hitherto little had been known as to the horizons from which they came; but now the Author, by careful collecting, had ascertained both the horizons and the localities from which each species was obtained. Then again, as regarded the arrangement of these teeth in the fish's jaws, very little was known—although Dr. Smith Woodward published some valuable information about this some years ago. The present Author, however, had obtained several examples with a number of teeth in their natural relations; and his study of these had largely extended the bounds of knowledge, and enabled him to show the wide variation in the form and pattern of the teeth contained in the mouth of one individual fish. The speaker congratulated the Author on the accomplishment of an extremely valuable and interesting piece of work.

Mr. W. Murton Holmes said that the group of teeth of *Ptychodus polygyrus* found by him was obtained from the upper part of the *Micraster cor-anguinum* Zone in the railway-cutting close to Banstead Station, about 24 feet below the surface.

Dr. A. Smith Woodward remarked on the exhaustive character of the Author's researches, and considered that he had now placed the naming of the teeth of *Ptychodus* on a satisfactory basis. The speaker regretted that there was still no clue to the predecessors of the genus, but was much interested in the Author's observation that the feebly-ridged teeth of *Pt. rugosus* occurred only in the Upper Chalk. He thought that recent discoveries still favoured the idea that *Ptychodus* was a forerunner of the Myliobatidæ and Trygonidæ, and alluded to the grooves just becoming evident in the roots of the teeth of *Apocopodon*, found in the uppermost Cretaceous rocks of Brazil and Africa.

Mr. G. W. Young confirmed the Author's statement as to the infrequency of the finding of *Ptychodus* teeth by the collector himself, compared with their abundance in museums. *Ptychodus* was not really a common fossil, but its teeth having a conspicuous colour, definite shape, and high lustre, readily caught the eye of the quarryman, who preserved every specimen that he saw. When purchasing specimens it was necessary to enquire carefully whether

they were found in the quarry in which they were offered for sale, for otherwise their value as evidence of zonal distribution might be lessened.

The AUTHOR thanked the Fellows present for their appreciative reception of his paper. He felt that the group of teeth discovered by Mr. Murton Holmes was one of the most important specimens that he had to bring before the meeting. In buying fossils from quarrymen he always exercised due caution, and was convinced that there was no doubt about any of the records that he had included in his paper.

9. *On some* MAMMALIAN TEETH *from the* WEALDEN *of* HASTINGS. By ARTHUR SMITH WOODWARD, LL.D., F.R.S., F.L.S., Sec.G.S. (Read March 22nd, 1911.)

SINCE the late Prof. Marsh's discovery of mammalian teeth and bones in the coarse grits of the Laramie Formation in Wyoming (U.S.A.), Mr. Charles Dawson, F.G.S., has persistently searched for similar fossils in deposits of the same nature in the Wealden formation of Sussex. These beds consist chiefly of coarse quartz-grains mingled with teeth of fishes and fragments of bones, and were originally noticed by Mantell under the name of 'Tilgate Grit.' According to Mr. Dawson's observations, however, they form only small lenticular deposits, and occur at several horizons in the Wealden Series.

The first result of this search was the discovery of a molar of *Plagiaulax*, which I described and named *Pl. dawsoni* in 1891.[1] More recent work, in which Mr. Dawson has been helped by Messrs. P. Teilhard de Chardin and Félix Pelletier, has led to the finding of three additional specimens—two probably belonging to *Plagiaulax* itself, the third to a distinct though related genus. The first-described tooth was met with in the Wadhurst Clay behind St. Leonards, while the three new teeth were obtained from the Ashdown Sands of the Fairlight Cliffs near Hastings.

The two new molars which seem to belong to *Plagiaulax* are unfortunately very imperfect. In one the crown is seen to be closely similar to that of the original tooth of *Pl. dawsoni*. In the second specimen most of the crown has decayed, but the two divergent roots are well displayed, the one somewhat stouter than the other.

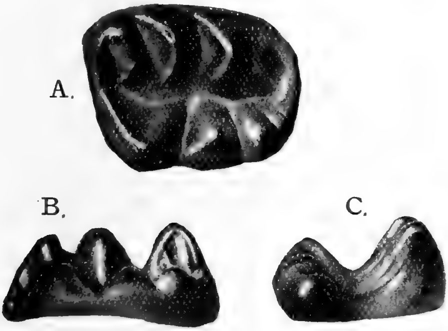
The third specimen is especially well preserved, and exhibits the whole of the crown, as shown in the accompanying text-figure (p. 279). It is a molar somewhat longer than wide, with nearly parallel sides and one end truncated a little obliquely, while the other is gently rounded: its total length does not exceed 2 millimetres. The crown is covered with dense smooth enamel, without any traces of wear, and so displays the exact shape and proportions of all the cusps. It is marked by a median longitudinal depression, which widens into a narrow flattened lip at the rounded end. On either side of the median depression is a row of three blunt cusps, of which those at the apparently internal border are the higher. The latter cusps are obtusely conical, the two at the rounded end being in close connexion, while the third at the truncated end is somewhat larger and well separated from the others by a cleft. The low external cusps approach a transversely-crescentic shape,

---

[1] 'On a Mammalian Tooth from the Wealden Formation of Hastings' Proc. Zool. Soc. 1891 (1892) pp. 585–86. A tooth of doubtful origin was subsequently described by Mr. R. Lydekker, 'On a Mammalian Incisor from the Wealden of Hastings' Q. J. G. S. vol. xlix (1893) pp. 281, 282.

and that at the rounded end is much the larger—not extending quite to the edge of the tooth, though occupying nearly half the length of the crown. The other two external cusps are almost equal in size, and are followed at the truncated border by a low transverse ridge, which thickens within the last external crescent and passes up nearly to the apex of the largest internal cusp. There is no trace of a cingulum along either the internal or the external border. The roots of the tooth are not exposed.

Dipriodon valdensis, *sp. nov.; crown of molar tooth, upper* (A), *outer* (B), *and terminal* (C) *views, 15 times nat. size.*



[Discovered by M. P. Teilhard de Chardin in the Ashdown Sands, Fairlight Cliffs, Hastings.]

This very small dental crown evidently belongs to one of the Multituberculata (or Allotheria), but its black shining enamel differs considerably in appearance from the paler coloured and faintly-cracked enamel of the other Wealden teeth which have been provisionally referred to *Plagiaulax*. It is also distinguished from the molars of the typical species of that genus by the arrangement and shape of the coronal cusps. These cusps spread far towards the middle of the tooth, and most of them, if much worn, would exhibit a crescentic shape; whereas the cusps in a corresponding molar of *Plagiaulax* are more closely confined to the raised marginal rim, and would not at any stage of wear expose a crescentic section. The new Wealden tooth must therefore be assigned to one of the so-called 'selenodont' Multituberculata, of which the Lower Jurassic *Stereognathus*[1] and the Upper Cretaceous *Meniscoessus* and *Selenacodon* are typical examples.[2] Some of the teeth of this group bear three, others only two rows of cusps; and it seems likely that animals with 3-ridged molars in one jaw would have 2-ridged

---

[1] R. Owen, 'Monograph of the Fossil Mammalia of the Mesozoic Formations' (Palæont. Soc. 1871) p. 18 & pl. i, figs. 27–30.

[2] See especially O. C. Marsh, 'Discovery of Cretaceous Mammalia' Amer. Journ. Sci. ser. 3, vol. xxxviii (1889) p. 86 & pl. ii.

molars opposed to them in the other jaw. The generic determination of isolated teeth is thus impossible, until a series of complete jaws has been discovered; but, as molars with a double row of crescentic cusps have already been noticed by Marsh[1] as species of '*Dipriodon,*' it is perhaps convenient to use this appropriately-descriptive name also for the new tooth now described. It represents a very much smaller species than either of those from the Upper Cretaceous of Wyoming named by Marsh, while the cusps of the dental crown are less regular in size and arrangement than in the latter. For purposes of reference the tooth may, therefore, be recorded under the name of *Dipriodon valdensis.*

Discussion.

Mr. C. Dawson thanked the Author for his kind encouragement and readiness at all times to assist in the determination of his specimens, and remarked that in the English Wealden there are three horizons where bone-beds constantly occur, namely:—(1) In the Upper Tunbridge Wells Sands, just below the Weald Clay (being the true 'Tilgate Grit' of Mantell); (2) at a great depth below the former, at the base of the Wadhurst Clay, in the blue clay above, and sometimes associated with, the thick bed of calcareous sandstone ('Blue Stone'); and (3) about 26 feet below No. 2 (at Hastings), at the top of the Ashdown Sand: it is less fossiliferous than either of the former, and is usually associated with bands of calcareous sandstone. So far, mammalian remains had not been discovered in No. 1: Nos. 2 & 3 had yielded the teeth ascribed to *Plagiaulax*, and now No. 3 had also furnished *Dipriodon.*

During the last twenty years the speaker had disintegrated and microscopically examined many tons of Beds 2 & 3; and during the last two years he had been favoured with the patient and skilled assistance of MM. P. Teilhard de Chardin and Félix Pelletier, to whom the discovery of the multituberculate tooth (*Dipriodon*) was due, as well as several new forms not mammalian. He was glad to be able to say that, by the kindness of his colleagues, all these specimens are to be ceded to the British Museum.

Prof. W. Boyd Dawkins, after an allusion to his find, in years gone by, of *Hypsiprymnopsis rhæticus,* expressed his pleasure that the bone-beds of the Wealden were being worked at steadily: there was a most wonderful development of these bone-beds in the neighbourhood of Battle. He hardly thought that the affinities of the mammalian teeth now described were with the Monotremes (Prototheria), but rather with the Marsupials (Metatheria). It was remarkable to find in the Eocene of both the European and the American continents so specialized a type as *Plagiaulax* ranging through from the Purbeck.

Dr. Henry Woodward bore testimony to the valuable services

---

[1] *Op. cit.* p. 85 & pl. ii, figs. 13–18.

rendered to palæontology by Mr. Charles Dawson, during more than twenty years, in the Wealden formation of Sussex. He commenced his work by obtaining a large series of excellent *Iguanodon* remains, now in the British Museum; but, of late, he had devoted his attention to the discovery of minute mammalian teeth. These Multituberculata were a most ancient and widespread type; indeed, *Tritylodon*, from the Trias of South Africa (now considered a Theriodont reptile), was described in 1884 as a primitive mammal by Owen. Charles Moore found *Microlestes* in the Rhætic, and Prof. Boyd Dawkins *Hypsiprymnopsis* at Frome; Beckles found many species in the Purbeck of Swanage, and so too Marsh in the Jurassic and Cretaceous of America; while Cope added the Eocene *Polymastodon* from New Mexico, and *Neoplagiaulax* had been added in France.

The Author, in reply, said he thought that, as the molars of *Plagiaulax* closely resembled the temporary teeth of the recent *Ornithorhynchus*, there was still reason to consider the Jurassic genus as Monotreme rather than Marsupial. The new teeth which he had described were essentially Jurassic in type, and so agreed with all the other vertebrates and plants found in the Wealden formation.

ADMISSION AND PRIVILEGES

OF

FELLOWS OF THE GEOLOGICAL SOCIETY OF LONDON.

EVERY Candidate for admission as a Fellow must be proposed by three or more Fellows, who must sign a Certificate in his favour. The Proposer whose name stands first upon the Certificate must have a personal knowledge of the Candidate.

Fellows on election pay an Admission Fee of Six Guineas. The Annual Contribution paid by Fellows is Two Guineas, due on the 1st of January in every year, and payable in advance; but Fellows elected in November or December pay no Contribution for the current year. The Annual Contribution may, at any time, be compounded for by a payment of Thirty-Five Pounds.

The Fellows are entitled to receive gratuitously all the volumes or parts of volumes of the Quarterly Journal of the Society that may be published after their election, so long as their Annual Contributions are paid; and they may purchase any of the publications of the Society at a reduction of 25 per cent. under the selling-prices.

The Library is open daily to the Fellows between the hours of 10 and 5 (except during the fortnight commencing on the first Monday in September; see also next page), and on Meeting-Days until 8 P.M. Under certain restrictions, Fellows are allowed to borrow books from the Library.

Publications to be had of the Geological Society, Burlington House.

QUARTERLY JOURNAL. (Vols. III to LXVI, inclusive.)

Price to Fellows, 13*s*. 6*d*. each (Vols. XV, XXIII, XXX, and XXXIV to LXVI, 16*s*. 6*d*.), in cloth.

GENERAL INDEX TO THE FIRST FIFTY VOLUMES OF THE QUARTERLY JOURNAL (1845–1894). Part I (A–La). Part II (La–Z). Price 5*s*. each. To Fellows 3*s*. 9*d*. each. [Postage 3*d*.]

GEOLOGICAL LITERATURE added to the Geological Society's Library during the years ended December 31st, 1894–1909. Price 2*s*. each. To Fellows, 1*s*. 6*d*. each. [Postage 3*d*.]

THE HISTORY OF THE GEOLOGICAL SOCIETY OF LONDON, by H. B. WOODWARD, F.R.S. Price 7*s*. 6*d*. To Fellows, 6*s*. [Postage 6*d*.]

THE CENTENARY OF THE GEOLOGICAL SOCIETY OF LONDON, recorded by W. W. WATTS, F.R.S. Price 2*s*. net. [Postage 3*d*.]

LIST OF THE TYPE- AND FIGURED SPECIMENS recognized by C. D. SHERBORN in the Collection of the Geological Society, verified and arranged, with additions, by the Rev. J. F. BLAKE. 1902. Price 3*s*. 6*d*. (bound in cloth); 3*s*. 0*d*. (in paper wrappers). To Fellows, 2*s*. 6*d*. and 2*s*. 0*d*. [Postage 3*d*.]

HUTTON'S 'THEORY OF THE EARTH,' Vol. III., edited by Sir ARCHIBALD GEIKIE, D.C.L., F.R.S. Price 3*s*. 6*d*. To Fellows, 2*s*. [Postage 4*d*.]

THE GEOLOGY OF NEW ZEALAND. Translated by Dr. C. F. FISCHER from the works of MM. HOCHSTETTER & PETERMANN. With an Atlas of Six Maps. Fellows may purchase one Copy of this Book at 2*s*. Additional Copies will be charged 4*s*. [Postage 5*d*.]

CONTENTS.

PAPERS READ.

[No. 267 of the Quarterly Journal will be published next August.]

[The Editor of the Quarterly Journal is directed to make it known to the Public that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

⁂ The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

The Library and Museum at the Apartments of the Society are open every Weekday from Ten o'clock until Five, except during the fortnight commencing on the first Monday in September, when the Library in closed for the purpose of cleaning; the Library is also closed on Saturdays at One P.M. during the months of August and September. It is open until Eight P.M. on the Days of Meeting for the loan of books, and from Eight P.M. until the close of each Meeting for conversational purposes only.

Vol. LXVII. AUGUST 31st, 1911. **No. 267.**
Part 3.

THE
QUARTERLY JOURNAL
OF THE
GEOLOGICAL SOCIETY.

EDITED BY

THE ASSISTANT-SECRETARY.

[With Fourteen Plates and One Folding Table, illustrating Papers by Mr. E. S. Cobbold, Mr. H. Bolton, Prof. S. H. Reynolds & Dr. A. Vaughan, Mr. F. G. Collins, and Mr. A. Wade.]

LONDON:

LONGMANS, GREEN, AND CO.

PARIS:—CHARLES KLINCKSIECK, 11 RUE DE LILLE.

SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

Price Five Shillings.

LIST OF THE OFFICERS AND COUNCIL OF THE
GEOLOGICAL SOCIETY OF LONDON.

Elected February 17th, 1911.

President.

Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.

Vice-Presidents.

Charles William Andrews, B.A., D.Sc., F.R.S.
Alfred Harker, M.A., F.R.S.
John Edward Marr, Sc.D., F.R.S.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.

Secretaries.

Prof. Edmund Johnston Garwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S.

Foreign Secretary.

Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.

Treasurer.

Aubrey Strahan, Sc.D., F.R.S.

COUNCIL.

Henry A. Allen.
Tempest Anderson, M.D., D.Sc.
Charles William Andrews, B.A., D.Sc., F.R.S.
Henry Howe Arnold-Bemrose, J.P., Sc.D.
George Barrow.
Prof. Thomas George Bonney, Sc.D., LL.D., F.R.S.
Prof. William S. Boulton, B.Sc.
James Vincent Elsden, D.Sc.
John Smith Flett, M.A., D.Sc.
Prof. Edmund Johnston Garwood, M.A.
Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.
Alfred Harker, M.A., F.R.S.
Robert Stansfield Herries, M.A.
Bedford McNeill, Assoc.R.S.M.
John Edward Marr, Sc.D., F.R.S.
George Thurland Prior, M.A., D.Sc.
Prof. Sidney Hugh Reynolds, M.A.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.
Aubrey Strahan, Sc.D., F.R.S.
Herbert Henry Thomas, M.A., B.Sc.
Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.
Rev. Henry Hoyte Winwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

Assistant-Secretary, Clerk, Librarian, and Curator.

L. L. Belinfante, M.Sc.

Assistants in Office, Library, and Museum.

W. Rupert Jones. Clyde H. Black.
Arthur Greig.

STANDING PUBLICATION COMMITTEE.

Prof. W. W. Watts, *President.*

Prof. E. J. Garwood, } *Secretaries.*
Dr. A. Smith Woodward, } *Secretaries.*

Mr. H. A. Allen.
Dr. C. W. Andrews.
Dr. J. V. Elsden.
Dr. J. S. Flett.
Mr. A. Harker.
Mr. R. S. Herries.
Dr. J. E. Marr.
Dr. G. T. Prior.
Prof. S. H. Reynolds.
Prof. W. J. Sollas.
Dr. A. Strahan.
Mr. H. H. Thomas.

EVENING MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

Session 1911–1912.

	1911.	
Wednesday,	November	8*—22*
,,	December	6—20*
	1912.	
Wednesday,	January	10*—24*
,,	February (*Anniversary,* Friday, Feb. 16th) ...	7*—28*
,,	March	13*—27
,,	April	17*
,,	May	1—15*
,,	June	5—19*

[*Business will commence at Eight o'Clock precisely.*]

The asterisks denote the dates on which the Council will meet.

rendered to palæontology by Mr. Charles Dawson, during more than twenty years, in the Wealden formation of Sussex. He commenced his work by obtaining a large series of excellent *Iguanodon* remains, now in the British Museum; but, of late, he had devoted his attention to the discovery of minute mammalian teeth. These Multituberculata were a most ancient and widespread type; indeed, *Tritylodon*, from the Trias of South Africa (now considered a Theriodont reptile), was described in 1884 as a primitive mammal by Owen. Charles Moore found *Microlestes* in the Rhætic, and Prof. Boyd Dawkins *Hypsiprymnopsis* at Frome; Beckles found many species in the Purbeck of Swanage, and so too Marsh in the Jurassic and Cretaceous of America; while Cope added the Eocene *Polymastodon* from New Mexico, and *Neoplagiaulax* had been added in France.

The Author, in reply, said he thought that, as the molars of *Plagiaulax* closely resembled the temporary teeth of the recent *Ornithorhynchus*, there was still reason to consider the Jurassic genus as Monotreme rather than Marsupial. The new teeth which he had described were essentially Jurassic in type, and so agreed with all the other vertebrates and plants found in the Wealden formation.

10. TRILOBITES *from the PARADOXIDES* BEDS *of* COMLEY (SHROPSHIRE). By EDGAR STERLING COBBOLD, F.G.S. *With* NOTES *on some of the* ASSOCIATED BRACHIOPODA, *by* CHARLES ALFRED MATLEY, D.Sc., F.G.S. (Read April 5th, 1911.)

[PLATES XXIII–XXVI.]

Introductory Remarks.

IN a previous communication [1] I called attention to certain trilobites associated with *Callavia* [2] *callavei* Lapw., from the limestones at the top of the Lower Comley Sandstone, and indicated the correspondence of many of the forms with those of Dr. Matthew's *Protolenus* Fauna from the Cambrian of the Atlantic province of North America.

The object of the present paper is to describe and figure the trilobites of the Upper Comley Sandstone, and to endeavour to estimate the faunal importance of the physical break between the upper and the lower groups of strata.

Many of the specimens have been obtained during the progress of the excavations that I have been conducting for the British Association; others have been collected at various times during the past twenty years; and, through the kindness of Prof. Charles Lapworth, I have had access to the type-specimens of his *Paradoxides groomii,* which are now figured for the first time.

The fossils described in this paper occur at three distinct horizons. A lower one, the Quarry-Ridge Grits, at the base of the *Paradoxides*-bearing beds of the Comley Sandstone, where they rest unconformably upon the *Protolenus* and *Callavia* Beds; a second, the Hill-House Beds, some 300 feet higher in the succession; and a third, the Shoot-Rough-Road Beds, near the top of the Comley Sandstone Group, presumably several hundreds of feet higher.

The stratigraphical relations of these beds to one another and to the strata above and below them, the local names adopted, and the horizons from which the principal fossils have been collected, are shown in the vertical section published in my report to the British Association Committee for the Excavation of Critical Sections in the Palæozoic Rocks of Wales & the West of England.[3]

---

[1] Q. J. G. S. vol. lxvi (1910) pp. 19–51 & pls. iii–viii.

[2] See Smithsonian Misc. Coll. vol. liii, No. 1934 (Aug. 1910), where Dr. Walcott adopts Dr. Matthew's term *Callavia* as a distinct generic name for *O. (Holmia) bröggeri, O. (Holmia) callavei,* and other species (pp. 274 *et seqq.*).

[3] Rep. Brit. Assoc. 1910 (Sheffield) p. 121.

SYNOPSIS OF PART OF THE CAMBRIAN ROCKS OF COMLEY, SHOWING THE POSITIONS OF THE FOSSILIFEROUS HORIZONS (in descending order).

Shoot-Rough-Road Beds.	Shale.	*Orthis (Orusia)* cf. *lenticularis* Wahl.
	Gritty flags.	*Davidis* Fauna.
	Sandstone.	*Paradoxides rugulosus* Corda.
	Unexplored interval.	
Hill-House Beds.	Shale.	
	Grits.	*Ptychoparia (Liostracus)* sp.
	Calcareous flags.	*Dorypyge lakei*, sp. nov.
Quarry-Ridge Beds.	Shale.	
	Coarse grit and conglomerate.	*Groomii* Fauna.
	Unconformity and position of the Black Limestone.	
Lower Comley Sandstone.	The Grey Limestones.	*Protolenus-Callavia* Fauna.
	The *Olenellus* Limestone.	
	Sandstone, with occasional calcareous bands.	

Description of the Trilobites.

Paradoxides Brongniart.

PARADOXIDES GROOMII Lapworth. (Pl. XXIII.)

C. Lapworth, Geol. Mag. dec. iii, vol. vii (1891) p. 532, footnote.

In the above-cited paper on *Olenellus callavei*, Prof. Lapworth gives the following preliminary description of *Paradoxides groomii*:—

> 'In general form and size intermediate between *Par. Harlani* (Green) and *Par. Davidis* (Salter). Length 8 to 9 inches, breadth 5½. Head semicircular, with pointed genal spines from 2 to 3 inches in length. Glabella prominent, clavate, more than half its length being occupied by the broadly rounded and smooth frontal lobe. Hypostoma of the type of that of *Par. Bohemicus* (Boeck). Pleuræ (No. ?) falcate, and sharply pointed. Pygidium a raised disc with a central tubercle; embraced laterally by long, sabre-like, distally-diverging spines. Localities—Neves Castle (Lapworth, 1889) and Comley (Groom, 1890). Named after T. Theo. Groom, Esq., B.Sc., who first collected fragments sufficient for description.' (*Op. cit.* pp. 532–33.)

The type-specimens sent to me by Prof. Lapworth are to be found upon four slabs of calcareous conglomerate from Comley Quarry, lettered A, B, C, & D, and one piece of a rather different rock from Neves Castle. Upon the slabs from Comley there are, also, several examples of cranidia and pygidia of *Dorypyge lakei*, sp. nov. (described below, p. 287), and also two of a long, tapering Hyolithoid shell of circular section, which I recognize as being identical with other specimens that I have collected from the same locality and bed.

The fossil fragments in the conglomerate of Comley Quarry usually occur matted together in clots of calcareous material about

1 foot above the actual base of the conglomeratic Quarry-Ridge Grits. In some cases these clots pass by insensible gradations into the glauconitic sandy matrix, in others they have sharp boundaries as though they were included blocks of pre-existing rock; but it is possible to collect specimens of the clots with a well-defined boundary on one side, while on the other the calcareous material passes gradually into the sandy matrix. The fossils of the clots, which include *Dorypyge*, *Conocoryphe*, *Stenotheca*, and the Hyolithoid shell, in addition to the fragments of *Paradoxides*, are also found sporadically in the sandy matrix. I am, therefore, confident that the calcareous clots are of the same geological age as the deposition of the grits.

Curiously enough, side by side with these calcareous clots, fragments of limestone are to be found, containing recognizable portions of trilobites of the *Protolenus-Callavia* Fauna and derived from the underlying Lower Comley Sandstone.

In addition to the type-specimens, a great number of fragments have passed through my hands, but only two of these throw additional light upon the species. These are portions of thoracic segments which fell to the hammer of Mr. W. G. Fearnsides on a recent visit to the locality, and one part of a pygidium which I uncovered on Slab A in trying to develop the margin of the glabella.

Specimen [1307] [1] (Pl. XXIII, fig. 6) shows that the axial lobe was narrow as compared with the total width of the thorax (apparently the proportion is only a fifth), and that it had a very slight convexity. A second fragment [1308] (Pl. XXIII, fig. 8) appears to belong to the posterior part of the thorax, where the falcate extremity is curved backwards to a much greater degree than obtains in [1307] or in [B_{12}] (fig. 7).

The fragment of a pygidium [A_5] (Pl. XXIII, fig. 9), taken in conjunction with [A_6] (not figured), shows that the shield was of the same rounded type as those of *Paradoxides bohemicus* Boeck and *P. tessini* L.

The more noticeable features of the species, so far as at present known, are (1) the general flatness of the whole shield; (2) the width and slight convexity of the margin of the free cheek and, by inference, of the whole margin of the head-shield; (3) the pronounced smoothness of the upper surface; (4) the rugosities of the doublure; and (5) the comparative narrowness of the axial lobe.

The species seems to be most nearly related to *Paradoxides regina* Matthew,[2] which is described as an 'unusually smooth species' (*op. cit.* p. 120), but has 'obscure, scattered tubercles' on the cranidium, which are not seen in the specimens from Comley. The

---

[1] [The numbers and letters in square brackets are those attached to the specimens. Where numbers alone occur, the specimens are in my collection for the Geological Excavations Committee of the British Association.—*E. S. C.*]

[2] Trans. Roy. Soc. Canada, vol. v (1887–88) sect. iv, p. 119 & pl. iii.

rugosities on the doublure appear from Dr. Matthew's figure to correspond in spacing and number with those seen in the Comley species, and the anterior marginal fold is wide and of little convexity in both.

They are sufficiently differentiated by the course of the facial suture posterior to the eye. In *Paradoxides regina* it is distinctly sigmoidal and extends widely outwards. In *P. groomii* it extends but little beyond the eye (see Pl. XXIII, fig. 4), and in this respect it approaches more nearly to *P. bennettii* Salter.[1]

The hypostoma of *P. groomii* differs from that of *P. regina* in being proportionately wider across the posterior part, and in being furnished with hooks at the postero-lateral angles.

The fragments from Comley indicate a length of from 20 to 25 centimetres for the complete trilobite, which is about half the length of Dr. Matthew's type-specimen, and of very much the same size as Salter's.

Locality and horizon.—Comley Quarry, from the conglomeratic base of the Quarry-Ridge Grits; also from Neves Castle (Lapworth).

PARADOXIDES spp. indet. (Pl. XXIV, figs. 1–7 *c*.)

From some detached blocks of the material that has yielded the *Dorypyge* and *Conocoryphe* described below, I have before me a number of fragments of smaller *Paradoxides*, which indicate two or three distinct species.

Locality and horizon.—Comley Quarry, from the conglomeratic portion of the Quarry-Ridge Grits.

PARADOXIDES DAVIDIS Salter. (Pl. XXIV, figs. 17 *a*, 17 *b*, & 18.)

J. W. Salter, Q. J. G. S. vol. xx (1864) p. 234 & pl. xiii, figs. 1–2; and Mem. Geol. Surv. dec. xi (1864) pl. x.

My collection contains many fragments of head-shields, pleuræ, etc., which agree with Salter's species, but do not indicate very large examples of it. The reference is confirmed by the two pygidia [319, 321] which are figured.

The larger specimen (fig. 17) appears to me to be of the normal form, but the smaller (fig. 18) differs slightly in the shape of the posterior margin between the two points and in the contour of the sides. As has been suggested to me by Mr. Lake, it may be the pygidium of a young individual of the species.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley, about 400 yards north-east of the Quarry; from the ochreous band about 4 feet below the top of the Shoot-Rough-Road Flags.

---

[1] Q. J. G. S. vol. xv (1859) p. 553, text-figure.

Paradoxides rugulosus Corda. (Pl. XXIV, figs. 14–16 *c*.)

I. Hawle & A. J. C. Corda, 'Prodr. Monogr. Böhm. Trilob.' 1847, p. 32.
J. Barrande, 'Syst. Silur. Bohême' vol. i (1852) p. 374, pl. ix, fig. 31 & pl. xiii, figs. 3–9, and Suppl. 1872, p. 11, pl. iii, fig. 36.

This species is represented by a number of cranidia and other fragments, usually in the state of very friable casts in rottenstone. These are in accord with Barrande's figures and descriptions in all points, except that the rugosities on the anterior lobe and sides of the glabella appear to be more strongly pronounced (see Pl. XXIV, figs. 15 *a* & 15 *b*).

I was so much impressed with these rugosities, that I sent the specimen figured to Dr. G. F. Matthew, with the inquiry whether it was related at all closely to the Acadian *P. lamellatus* Hartt. He very kindly replied that the rugosities of the Shropshire form differ from those of *P. lamellatus* in being 'shorter, lower, and more numerous.'

The pygidium (figs. 16 *a*–16 *c*) appears to me to be of the same form as those from Bohemia. Dr. Matthew adds that a complete cranidium, of which I sent him a drawing, 'is a very good *eteminicus* or *rugulosus*,' but that the pygidium is not like that of the Acadian *P. eteminicus*.

Locality and horizon.—Excavation No. 23 in a field near the upper section on the Shoot-Rough Road, Comley; from a calcareous band at the summit of the Shoot-Rough-Road Sandstone, about 14 feet below the band which yielded *Paradoxides davidis* and the associated brachiopoda.

Conocoryphe Corda.

Conocoryphe emarginata Linnarsson, var. longifrons, nov. (Pl. XXIV, figs. 8–13.)

J. G. O. Linnarsson, 1876–77, Geol. Fören. Stockholm Förhandl. vol. iii, p. 366, & pl. xv, figs. 2 *a*–4.

In my collection there are fragments of several head-shields of a trilobite, which seems nearly allied to Linnarsson's species from Stora Frö, but whether it should be regarded as a local variety or as a distinct species, must depend upon the weight given to the several divergences, which are as follows :—

(1) The Comley cranidia are longer, more convex, and more quadrate in outline than the Scandinavian form. In the former the facial sutures converge but gently forwards, whereas in the latter they are inclined at a considerable angle to the axial line.

(2) The glabellas from Comley are long, strongly elevated and somewhat campanulate in outline, and have only very faint traces of the lateral furrows, whereas Linnarsson's fig. 2 *a* shows a comparatively short, conical glabella with well-marked furrows.

(3) The marginal rim (and concurrently the intramarginal furrow) of the Comley form varies somewhat. In some specimens (Pl. XXIV, fig. 12 *a*) it is only just marked off by a change of curvature, in others (fig. 13) it is separated from the rest of the

front by a distinct groove, but this is never so deep or wide as that shown in Linnarsson's fig. 2 *b*.

In the Comley form the axial furrow varies in the same manner as the intramarginal furrow, but is never very strongly marked.

The TEST appears to be very thick and strong, and shows minute granulations on the outer surface with interspaces, which in places sink to little pits, too ill-defined to be called punctæ. The internal casts (figs. 12 & 13) show, upon the glabella and proximate parts of the cheek, closely-set granulations indicating depressions on the interior of the shell; towards the postero-lateral angles these become successively coarser and, in front of the mark corresponding to the ocular ridge, they are much elongated and arranged in waving, irregular, discontinuous lines radiating towards the margin of the shell; in front of the glabella the granulations gradually split up into shorter lengths.

FREE CHEEK: There are in my collection three specimens of free cheeks which are associated with the cranidia, and probably belong to the same species.

The peculiar fragment shown in Pl. XXIV, fig. 11, gives a view of the under side. It shows a strong and considerably elongated genal spine, at the base of which there is a fold or ridge, and from this the doublure sinks into the matrix to follow the curvature of the upper side. Fig. 10 shows a fragment of, probably, the upper side. In both specimens the surface is finely granular.

PYGIDIUM (Pl. XXIV, figs. 9 *a*–9 *c*): On a specimen kindly lent to me by Mr. H. C. Beasley is an incomplete external cast of a pygidium, which agrees, so far as it goes, with Linnarsson's fig. 4. The convexity is very pronounced (fig. 9 *b*); the axis shows three divisions, in addition to the articulating facet and the bluntly rounded end; and the lateral lobe shows two well-marked furrows, with a faint indication of a third.

Locality and horizon.—Comley Quarry; from the conglomeratic base of the Quarry-Ridge Grits.

Dorypyge Dames.

I have fragments of at least twenty head-shields and as many pygidia which come under this genus, and were derived from the two horizons which I call the Quarry-Ridge Grits and the Hill-House Flags. The specimens from the former, although fragmentary, are excellently preserved, while those from the latter are very fragile casts.

DORYPYGE LAKEI, sp. nov. (Pl. XXV, figs. 1–8 & text-fig. on p. 291.)

I take as type-specimens the two head-shields lying side by side [1163], figured to natural size (Pl. XXV, fig. 2) These exhibit all the parts of the cranidium, and consequently I am able to make a complete restoration of it (Pl. XXV, figs. 1 *a*–1 *c*).

I dedicate this species to Mr. Philip Lake, who has so frequently befriended me in my study of the Comley trilobites, and who first pointed out to me the reference of these fossils to Dames's genus.

CRANIDIUM: General form.—Irregularly pentagonal, with the anterior border rounded in front of the glabella, but nearly straight in its continuation towards the sides.

Size.—Moderate; length of the type-specimens = about 8 millimetres, exclusive of the spine; width, across the eye-lobes = about 10 mm., across the posterior angles = about 11 mm. Other specimens indicate lengths varying from $2\frac{1}{2}$ to 20 mm., exclusive of the spine.[1]

General convexity.—Very strongly marked, about 1:2.4[2] in the type-specimens, about 1:3 in others.

Glabella.—Strongly convex, both transversely and longitudinally; distinct from the occipital ring; about five-sixths of the total length of the shield, exclusive of the spine; the sides are nearly straight, and converge more or less rapidly backwards; the width of the most convergent glabella at the anterior third is about three-quarters of the length of the glabella, while at the posterior end it is not much more than half that length; there is no trace of any furrow to be seen, unless it be the little pit on the line of the axial furrow, and a modification of the surface-markings, mentioned below.

Occipital furrow.—Well defined; rather narrow, and fairly uniform, in both width and depth, throughout; very straight in its course, but, when viewed from above, it appears to be slightly curved backwards by reason of the convexity of the glabella.

Occipital ring.—Of equal width with the base of the glabella; slightly broader in the middle than at the sides; armed with a short, sharp, and slightly curved spine, which rises from the posterior half of the ring, and is directed upwards and backwards; the ring is arched upwards very strongly as viewed from behind, and must have accommodated a very convex thoracic axis.

Axial furrow.—The glabella is very distinctly outlined by the change of curvature all round, but the furrow is scarcely at all impressed, except near the anterior ends of the sides of the glabella, where it sinks to a very distinct pit, which is impressed from the side rather than vertically downwards, and may represent one of the glabellar furrows (see Pl. XXV, figs. 1 & 5).

Fixed cheeks.—Triangular in the view from above; convex; nearly horizontal close to the glabella, but curving down rapidly to the eye-lobe and also both forwards and backwards.

Eye-lobe.—Small, about a sixth of the total length of the head-shield; at a low level as compared with the cheek, from which it projects horizontally; not raised at the edge; situated about midway in the length of the cranidium.

Ocular ridge.—Obsolete.

---

[1] The size of the largest head-shield collected points to a total length, in the complete trilobite, of 60 to 70 millimetres.

[2] These numerals represent the proportion of the height of the shield to its width.

Postero-lateral margin.—Consisting of a narrow convex rim and a wide, well-rounded groove between it and the cheek; near the glabella the limb is almost horizontal, but farther out it curves evenly and rapidly down to the postero-lateral angle, without any decided point of geniculation.

Front.—Consisting of a very narrow convex border in front, widening somewhat outwards, and having a rather wide groove in its rear.

Facial suture.—Anterior branch, as seen from above (Pl. XXV, fig. 1 *a*), convergent forwards and very short; as seen from the side (fig. 1 *b*) considerably longer and curved down to the groove inside the marginal rim, beyond which it cuts the rim almost horizontally. Posterior branch, as seen from above (fig. 1 *a*), divergent and nearly straight to the postero-lateral angle, which is situated distinctly farther out than the eye-lobe; as seen from the side (fig. 1 *b*), this branch is somewhat sigmoidal and rather long. The two branches of the suture, as seen from above, are almost in one straight line from the anterior to the posterior angles; but, if the cranidium were flattened out, or had lost its great convexity, the posterior branch would have a wide outward extension.

Test.—The whole of the outside of the head-shield is thickly covered with short, irregular, subparallel, raised lines (~~Pl. XXV, fig. 5~~). These lines are longer on the front of the glabella than on its posterior part; on the cheeks they are much shorter; while on the frontal rim they are considerably elongated. It is just possible to detect interruptions of the rugose markings at the sides of the glabella where the lateral furrows would occur. The cheeks, taken alone, might be described as granular; but there is a distinct gradation in the surface-characters from one part of the shell to another.

In order to indicate the variations in size and in the shape of the glabella, three additional figures (figs. 3, 4, & 5), drawn to the same scale as the restoration of the cranidium, are given.

Free cheek: One very imperfect fragment of a free cheek from the Hill-House Flags shows that it bore a strong rounded spine at the genal angle, set so as to project horizontally outwards in agreement with the spines on the pleuræ and pygidium.

Thorax: I have five or six specimens showing the pleuræ; of these two of the most complete are illustrated (Pl. XXV, figs. 6 & 7). They consist, longitudinally, of three parts: a horizontal proximate part, an inclined median part, and a distal spine that is nearly horizontal. The length of the spine is about equal to that of the proximal part, while that of the median part is rather less. The pleuræ have a well-rounded groove occupying one-half of the total width.

Pygidium (Pl. XXV, figs. 8 *a*–8 *c*): Size.—Moderate; length, exclusive of the spines, = 8 millimetres, greatest width = about 11 mm.

General form.—Sub-semicircular, with a strongly convex axis, convex side-lobes, and a flattened, horizontal, spinose border.

General convexity.—About 1 : 3.5.

Axial lobe.—Strongly convex in cross-section, and considerably curved longitudinally; slightly narrowing posteriorly; greatest width equal to about a third of that of the pygidium; divided by six deep and wide furrows into an anterior, articulating facet, and six other segments of subequal breadth: of these, the five anterior are provided with short, strong, and straight spines projecting upwards and backwards; the sixth or terminal segment has a well-marked node in place of a spine, and ends in a steep slope down to the flattened border of the shield.

Axial groove.—Very slightly marked along the sides of the axis.

Lateral lobes.—Sub-triangular; evenly convex outwards; not connected together behind the axis; each lobe consists of six ribs; the anterior rib is narrow and rounded; the next three are much wider and have their surfaces flattened transversely to their length, and indistinctly marked with a wide furrow; the two remaining ribs are small, and only just discernible.

Border.—Horizontal, and continuous round the sides and end of the pygidium; the width, exclusive of the spines, is about a tenth of the length of the shield; the margin is armed with six spines of flattened, oval section on each side. So far as can be seen from the specimens, the length of these spines is sensibly the same throughout, except, perhaps, in the case of the hindermost pair, which have their bases slightly enlarged.

Test.—The outer surface of the most perfect specimen [181] (Pl. XXV, fig. 8 *a*) is a little corroded, and exhibits a finely granular surface. Other fragments [183, 184] have their surfaces thickly covered with raised granules, all the way from the axis to the spines. This granulation is somewhat more minute than that of the head-shield, but may be regarded as a further modification of that of the fixed cheeks.

The pygidia described are nearly allied to those of *Dorypyge oriens* Grönwall,[1] but differ in certain respects. In his species the two posterior marginal spines are much longer than the others, and have enlarged bases to correspond; they also diverge one from the other: while those of the Comley pygidia are little, if at all, longer than the rest, and project directly backwards in the line of the axial furrows. To judge by the figures and restoration given by Dr. Grönwall, the Bornholm species is somewhat narrower than the Shropshire form, and the five anterior pairs of spines are, proportionately, somewhat shorter.

The test of *Dorypyge oriens* is described as being smooth, while that of *D. lakei* is decidedly granular, and the glabella is quite rugose (see Pl. XXV, fig. 5).

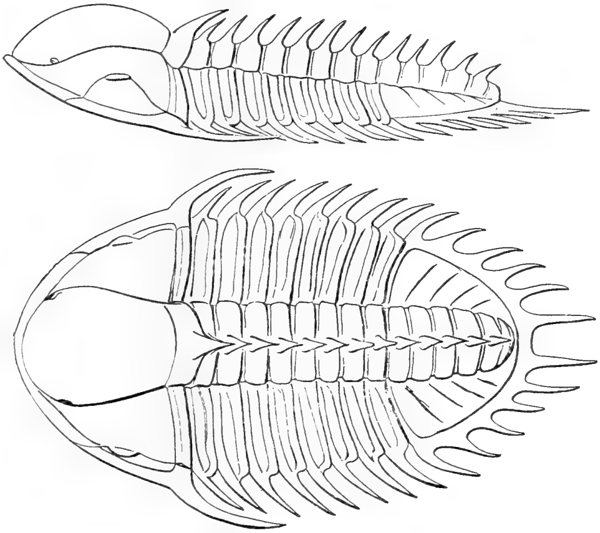
I have attempted a restoration in outline of this species (see the accompanying text-figure, p. 291). The number of thoracic segments (eight) is inserted from the analogy of other species. The

---

[1] K. A. Grönwall, Danmarks Geol. Undersög. ser. 2, No. 13 (1902) pp. 135 & 216, pl. iii, figs. 13–15.

free cheeks and thoracic axis are based on the evidence supplied by fragments from the Hill-House Beds. The axial spines are drawn to agree with the two or three towards the end of the pygidium seen in another specimen.

Side view and view from above of Dorypyge lakei, *sp. nov. Restored from fragments found at Comley (Shropshire): about three times the natural size of the type-specimens.*



Localities and horizons.—Comley Quarry, from the conglomeratic base of the Quarry-Ridge Grits; also from the Hill-House Flags that lie under the little quarry at the northern end of the ridge which bears that name; and again from the Quarry-Ridge Grits of Robin's Tump, Comley.

Agnostus Brongniart.

AGNOSTUS FALLAX Linnarsson. (Pl. XXV, figs. 17 *a*–18 *b*.)

J. G. O. Linnarsson, 'Vestergötlands Cambr. & Silur. Aflagr.' K. Svensk. Vetensk.-Akad. Handl. n. s. vol. viii (1869–70) No. 2, p. 81 & pl. ii, figs. 54, 55; and Geol. Fören. Stockholm Förhandl. vol. iii (1876–77) p. 371 & pl. xv, fig. 7.

This species is represented by the fragmentary head- and tail-shields figured. I am indebted to Mr. Philip Lake for help in their determination.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the ochreous band about 4 feet below the top of the Shoot-Rough-Road Flags.

Microdiscus.

MICRODISCUS sp., cf. M. PUNCTATUS Salt. (Pl. XXV, figs. 12 *a*–12 *c*.)

J. W. Salter, Q. J. G. S. vol. xx (1864) p. 237 & pl. xiii, fig. 11.

The specimen [1297] exhibits five or more imperfect internal casts of a minute form of pygidium, about $1\frac{1}{2}$ millimetres long, from which I have compiled the outline sketches (Pl. XXV, figs. 12 *b* & 12 *c*). None of the specimens show the complete number of the divisions of the axis, but I do not think that there could have been more than seven or at most eight, including the articulating and terminal portions. In this respect these pygidia differ from *M. punctatus* Salter, and from the related forms *M. scanicus* and *M. eucentrus* Linnarsson.[1]

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the Shoot-Rough-Road Flags, 1 or 2 feet below the ochreous band.

Agraulos Corda.

AGRAULOS (?) HOLOCEPHALUS Matthew. (Pl. XXV, figs. 9 *a*–11 *c*.)

G. F. Matthew, Trans. Roy. Soc. Canada, vol. viii (1890–91) sect. iv, p. 138 & pl. xi, figs. 5 *a*–5 *d*.

Dr. Matthew's species appears to be represented by several cranidia, three of which [360–362] are figured. The last (Pl. XXV, fig. 9 *a*) has been much flattened by pressure, but the smallest (fig. 11 *a*) seems to retain its original convexity, which is very high (about 1 : 2.5).

The most convex specimen shows no sign of any marginal rim; but this feature is slightly marked in the other two specimens.

PYGIDIUM ? (Pl. XXV, figs. 16 *a*–16 *c*).—Associated in the same rock with these head-shields are two specimens of pygidia [376, 378] which may possibly belong to this species; but, so far as association goes, they might equally be referred to one or other of the two species next to be noticed.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the ochreous band, about 4 feet below the top of the Shoot-Rough-Road Flags.

AGRAULOS sp., cf. A. QUADRANGULARIS (Whitfield). (Pl. XXV, figs. 13, 14, & ? 15.)

R. P. Whitfield, Bull. Amer. Mus. Nat. Hist. vol. i (1884–86) p. 147 & pl. xiv, fig. 8.
C. D. Walcott, U.S. Geol. Surv. Bull. No. 10 (1884) p. 48 & pl. vii, fig. 1.

A second species, which is probably referable to *Agraulos*, is indicated by specimens [369–371] from the same bed of rock as

---

[1] J. G. O. Linnarsson, 'De undre *Paradoxides* Lagren vid Andrarum' Sver. Geol. Undersökn. ser. C, No. 54 (1883) pp. 29 & 30, pl. ii, figs. 17–20.

those just described. They are, however, too imperfect to admit of exact identification.

Except for the marginal rim, which at best is but poorly defined, this form is very near to *Agraulos quadrangularis* (Whitfield), as figured by Dr. Walcott. The eye-lobe in the Comley form is possibly a little larger than that shown in his figure, and the front is somewhat less distinctly rounded. The similarity in the transverse view of the head with that of *A. (?) holocephalus* is very marked.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the ochreous band, about 4 feet below the top of the Shoot-Rough-Road Flags.

Ptychoparia Corda; subgenus **Liostracus** Angelin.

Mr. F. R. C. Reed, in his memoir on the Cambrian fossils of Spiti,[1] gives a valuable summary of the views expressed by various authors on the classification of the many forms that have been placed under the genera *Ptychoparia, Liostracus*, and *Conocephalites*, and finally adopts these three names as subgeneric terms. Following this arrangement, I place the three or four forms next to be described under the subgenus *Liostracus.*

PTYCHOPARIA (LIOSTRACUS) PULCHELLA, sp. nov. (Pl. XXVI, figs. 1 *a*–2.)

CRANIDIUM [353]: Size.—Moderate; length, exclusive of the occipital spine = 8 millimetres; width, across the eye-lobes = $9\frac{1}{2}$ mm., across the posterior angles = 12 mm., in front of the eyes = about 8 mm.

General form.—Trapezoidal, with well-rounded front; all features in strong relief.

General convexity.—Considerable; about 1 : 4.

Glabella.—Truncate-conical, with broadly round apex; strongly convex; slightly curved longitudinally; occupying about two-thirds of the length of the head-shield, omitting the spine; width = about a third of that across the eye-lobes; without furrows.

Occipital furrow.—Distinct; straight; not deep.

Occipital ring.—Almost entirely merged into the base of a sharp, pointed spine, which projects upwards and backwards, reaches to a higher elevation than the glabella, and extends back to a distance from the occipital furrow equal to about half the length of the glabella.

Axial furrow.—Wide; and well marked, both at the sides and at the apex of the glabella.

Fixed cheeks.—Gently and evenly convex in cross-section; most elevated about midway in the length of the head; falling steeply to the postero-lateral furrows and gently forwards; connected in advance of the glabella by the tumid part of the front.

---

[1] Pal. Indica, ser. xv, vol. vii, Mem. No. 1 (1910) pp. 13–18.

Eye-lobes.—Rather small; about a sixth of the total length of the head-shield without the spine, and situated a little behind the middle of the length of the glabella; having the outer edge distinctly raised, so that there is a hollow between it and the fixed cheek.

Ocular ridge.—A slightly raised ridge, curving back from the anterior ends of the sides of the glabella to the eye-lobe, near which it loses prominence.

Postero-lateral border.—The furrow runs in a straight line with the occipital furrow transversely to the axis of the head-shield; the fold widens considerably outwards, so that the actual margin diverges considerably from the line of the furrow.

Front.—Extending forwards for a distance equal to about half the length of the glabella and consisting of three subequal parts, a convex swelling connecting the fixed cheeks; a wide, rounded hollow, and a well marked, rounded marginal rim, which extends, with very little loss of strength, to the facial sutures.

Facial suture.—Not completely preserved in any specimen; anterior branch curving gently inwards from the eye-lobe; posterior branch diverging outwards at a gentle curve to the posterior angles.

TEST: Much weathered in all the specimens; but with indications of having been relatively thick (see Pl. XXVI, fig. 1 *b*); surface-characters unknown.

FREE CHEEKS: There are several free cheeks [372, 374, 375] to be seen on the same hand-specimens with the cranidia. They agree with them in size, in the character of the weathered test and in the contour of the rounded margin, which is prolonged backwards into a short spine of circular section. Specimen [372] (Pl. XXVI, fig. 2) shows the curves of the eye and of the facial suture, and I have very little hesitation in referring it to the species. The area of the cheek is separated from the rounded margin by a distinct hollow, and rises in a gentle convex curve to the place of the eye.

This species seems nearest to *Liostracus validus* Matthew, and it is also not far removed from *L. linnarssoni* Brögger; but from both it differs in the relative length of the glabella. The graceful curves of the cranidium suggest the specific name.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the ochreous band near the top of the Shoot-Rough-Road Flags.

PTYCHOPARIA (LIOSTRACUS) sp. indet. (Pl. XXVI, figs. 4 *a*–4 *c*.)

A form allied to *Pt.* (*L.*) *pulchella* occurs at a considerably lower horizon, which I call the Hill-House Grits. The only specimens that I have seen are, however, badly preserved, and it is impossible to give a detailed description of them.

As the figures show, this species or variety is less convex and has a wider and longer glabella than *Pt.* (*L.*) *pulchella*, also the

spine, anterior border, and anterior marginal hollow are less strongly developed. It would, moreover, appear to be a rather smaller form.

Locality and horizon.—The little quarry at the northern end of the Hill-House ridge; from the coarse grits, both above and below the thick beds of compact grit.

PTYCHOPARIA (LIOSTRACUS) sp. indet. (Pl. XXVI, figs. 3 *a*–3 *c*.)

Another form which I refer to the subgenus is represented by one imperfect external cast of a cranidium, preserved in a sandy grit [1113]. It is principally remarkable for the great elevation of the fixed cheeks, which are almost as high as the glabella, their maximum altitude being situated towards the outer edge.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the main mass of the Shoot-Rough-Road Flags, about 8 feet below their upper limit.

PTYCHOPARIA (LIOSTRACUS)? DUBIA, sp. nov. (Pl. XXV, figs. 19 *a*–21.)

Several small heads in my collection from the same rock-bed as *Pt.* (*L.*) *pulchella*, sp. nov., may possibly be young individuals, but there are so many differences that I am not quite sure that they belong even to the same genus. From *Pt.* (*L.*) *pulchella* they differ in the following respects:—(1) The glabella is parallel-sided instead of being truncate-conical; (2) there is no spine on the occipital ring; (3) the eye-lobes are proportionately larger; (4) the general convexity is greater; (5) the space in front of the glabella is more fully convex and, in consequence, the intramarginal hollow is narrow and sharp. I think, therefore, that it is best to describe them in full as a distinct species.

CRANIDIUM: Size.—Minute; length = from 2½ to 3½ millimetres.

General form.—Trapezoidal; features in high relief.

General convexity.—High; about 1 : 3.

Glabella.—Convex; parallel-sided; with rounded apex; distinct from the occipital ring; rather more than half the total length of the shield; externally without furrows; but one specimen, an interior [366] (Pl. XXV, fig. 21), shows two pairs of furrows directed somewhat backwards.

Occipital furrow.—Deeply impressed; continuous.

Occipital ring.—Convex; with the posterior margin curved backwards, almost semicircularly.

Axial furrows.—Very deeply impressed, both at the sides and round the apex of the glabella.

Fixed cheeks.—Nearly as wide as the glabella; transversely convex; continuous round the apex of the glabella, and of almost equal elevation throughout; widening out behind the eye-lobe, and falling steeply into the groove of the postero-lateral border.

Eye-lobe.—About a quarter of the length of the head-shield;

raised at the edge and situated about midway in the length of the shield.

Ocular ridge.—Distinct in the interior [366], fig. 21, but hardly visible in the other specimens.

Postero-lateral border.—Furrow narrow and strongly marked; fold convex and also narrow; the whole border, as seen from behind, curves evenly down without geniculation to the lateral angles, which extend farther out than the eye-lobes.

Front.—Consisting of the convex space which connects the fixed cheeks and a convex marginal rim, separated by a deep, distinct, and narrow furrow. When viewed from in front, the marginal rim is very much arched upwards in the middle.

Facial suture.—Anterior branch, a little uncertain, apparently convergent forwards from the eyes; posterior branch divergent backwards.

TEST: Imperfectly preserved.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the ochreous band, about 4 feet below the top of the Shoot-Rough-Road Flags.

Faunal Grouping of the Trilobites.

The trilobites of the Comley Sandstone fall naturally into three principal groups or faunas—an upper with *Paradoxides davidis*, a median with *P. groomii*, and a lower with *Protolenus* and *Callavia*.

When the fossils are collected carefully bed by bed, several minor groups make their appearance, which, so far as can be judged from my collection, are very distinct. The horizontal extent of the beds available for examination is, however, so limited, that it is quite possible that these differences may prove to be more apparent than real.

THE FAUNAL GROUPS OF THE COMLEY SANDSTONE IN DESCENDING ORDER OF OCCURRENCE.

DAVIDIS FAUNA.—Shoot-Rough-Road Flags.

Paradoxides davidis Salter.
Agnostus fallax Linnarsson.
Agraulos holocephalus Matthew.
Agraulos sp., cf. *Arionellus quadrangularis* Whitfield.
Microdiscus sp., cf. *M. punctatus* Salt.
Ptychoparia (Liostracus) pulchella, sp. nov.
Ptychoparia (Liostracus) sp. indet.
Ptychoparia (Liostracus) ? dubia, sp. nov.

Brachiopoda (identified by Dr. Matley):—

Lingulella cf. *L. ferruginea* Salter.
Lingulella (?) sp. indet. [1033].
Lingulella (?) sp. indet. [709–710].
Acrothele cf. *A. granulata* Linnarsson.
Acrotreta (Linnarssonia) sagittalis Salt.
Acrotreta aff. *A. socialis* von Seebach.
Billingsella lindstrœmi Linnarsson, var. *salopiensis*, nov.
Billingsella cobboldi, sp. nov.
Orthis (?) sp.

A minor group, which is perhaps separable from the *Davidis* Fauna.
Shoot-Rough-Road Sandstone.

Paradoxides rugulosus Corda.

Brachiopoda (identified by Dr. Matley):—

Lingulella cf. *L. ferruginea* Salter.
Lingulella (?) sp. indet. [1071, 1072].

A wide interval of unexplored ground, probably representing a thickness of several hundreds of feet of strata, intervenes between the Shoot-Rough-Road Beds and the next lower horizon known.

A minor group, which is perhaps separable from the *Groomii* fauna below.
Hill-House Beds.

Dorypyge lakei, sp. nov.
Ptychoparia (Liostracus) sp. indet., allied to *Pt. (L.) pulchella*, sp. nov.
Acrotreta and *Hyolithellus*, awaiting critical determination.

GROOMII FAUNA.—Quarry-Ridge Grits.

Paradoxides groomii Lapworth.
Paradoxides sp. indet. No. 1.
Paradoxides sp. indet. No. 2.
Paradoxides sp. indet. No. 3.
Conocoryphe emarginata Linnarsson, var. *longifrons*, nov.
Dorypyge lakei, sp. nov.
Stenotheca and *Hyolithellus*, awaiting critical determination.

An unworked group or fauna.—The Black Limestone.

PROTOLENUS-CALLAVIA FAUNA.—The Grey and *Olenellus* Limestones.

LOBATUS Group.—Upper portion of the Grey Limestone.

Microdiscus lobatus Hall.
Microdiscus comleyensis Cobbold.
Microdiscus speciosus Ford.
Anomocare platycephalum Cobbold.
Anomocare parvum Cobbold.
Agraulos (Strenuella) salopiensis Cobbold.
Mohicana lata Cobbold.
Mohicana clavata Cobbold.
Protolenus latouchei Cobbold.
Protolenus morpheus Cobbold.
Lingulella (?), *Kutorgina (?)*, *Scenella (?)*, *Hyolithus*, *Hyolithellus*, and *Helenia (?)* awaiting critical determination.

BELLIMARGINATUS Group.—Lower portion of the Grey Limestone.

Microdiscus bellimarginatus S. & F.[1]
Anomocare (?) pustulatum Cobbold.
Callavia cobboldi Raw MS.
Callavia callavei Lapworth.
Lingulella (?), *Linnarssonia (?)*, *Kutorgina (?)*, *Obolus (?)*, *Orthis (?)*, *Hyolithellus*, and *Helenia (?)* awaiting critical determination.

---

[1] This species has been identified since the publication of my previous paper on some small trilobites from Comley, Q. J. G. S. vol. lxvi (1910) pp. 19-51.

HELENA Group.—The *Olenellus* Limestone.

Microdiscus helena Walcott.
Micmacca(?) ellipsocephaloides Cobbold
Do. do. var. *senior* Cobbold.
Do. do. var. *strenuelloides* Cobbold.
Do. do. var. *spinosa* Cobbold.
Micmacca (?) parvula Cobbold.

Callavia callavei Lapworth.
Callavia cartlandi Raw MS.
Ptychoparia (?) attleborensis S. & F.
Ptychoparia (?) annio Cobbold.
Iphidea(?), *Kutorgina(?)*, *Lingula(?)*, *Linnarssonia (?)*, *Hyolithus*, *Hyolithellus*, and *Stenotheca*, awaiting critical determination.

The generic references, particularly those in the lowest of the three faunas, are more or less provisional, and will require careful revision, before the divergences shown in the table between the component groups of the *Protolenus-Callavia* Fauna are thoroughly established. It may well be that further study of the forms, or further work in the field, will bring them much closer together than they seem to be at present.

As they now stand, there is no species of trilobite which passes the higher of the two dividing-lines, and even the genera seem entirely different. The lower dividing-line, according to my present determinations from very fragmentary specimens, is crossed by one important species, *Callavia callavei* Lapw. It seems probable that some of the brachiopoda, Hyolithidæ, etc., will also be found to pass the dividing lines, and so link up the three groups into one fauna.

The divergence between the *Protolenus-Callavia* Fauna and the *Groomii* Fauna is very complete. No genus among the trilobites[1] passes from one to the other, and the forms of *Stenotheca* and *Hyolithellus* that I have collected from the upper beds are quite distinct from those of the lower.

This divergence of faunas is accompanied by a well-marked unconformity to which I refer in more detail below; but I would again call attention to the Black Limestone of Comley Quarry, which comes in between the Grey Limestones with *Microdiscus lobatus* and the Quarry-Ridge Grits. It contains a group of fossils (trilobites, Hyolithidæ, brachiopoda, etc.) that is, possibly, intermediate between the *Protolenus-Callavia* and the *Groomii* Faunas. The trilobites are, however, so fragmentary and so difficult of extraction, that I am compelled to await the evidence afforded by the other fossils, before I can indicate the relations of this band to the strata above and below it.

The Unconformity.

The evidence for the unconformity between the Middle and the Lower Cambrian of Comley formerly consisted in the included blocks of the conglomeratic base of the Quarry-Ridge Grits, and in the

---

[1] It must be noted that the genus *Microdiscus* reappears in the *Davidis* Fauna, as in other regions. It is very doubtful whether the *Ptychopariæ (?)* of the *Olenellus* Limestone are properly referable to Corda's genus.

change of faunas to which Prof. Lapworth called attention in 1891.[1] It has received conclusive corroboration from the excavations of 1909 and 1910 for the British Association[2] in the isolated hill called Robin's Tump, about half-a-mile south of Comley Quarry.

The basement deposits of the Middle Cambrian are now found in contact with: (1) the Grey Limestones yielding *Protolenus*, *Strenuella*, etc. (in the Quarry Ridge); (2) the *Olenellus* Limestone yielding *Callavia*, etc. (in Dairy Hill); and (3) the underlying green sandstones, some depth below their summit (in Robin's Tump), and in this last there is undoubted evidence that the contact is due to unconformity.

The duration of the interval represented by the change of faunas finds a parallel in the time required for the physical break. How much of the life-history of this interval may be provided by the fossils of the Black Limestone is a problem that remains to be worked out.

General Conclusions.

(1) An unconformity occurs at the top of the Lower Cambrian rocks of Comley, which trenches somewhat deeply into that series and cuts out any upper members that may have existed.

(2) The highest of the Lower Cambrian beds at present known yield what appear to be successive modifications of a fauna closely allied to Dr. Matthew's *Protolenus* Fauna, and characterized in part by the presence of several members of the genus *Callavia*.

(3) Many of the trilobites of these beds are identical with, or closely allied to, species which occur low down in the series in America, and many hundreds of feet below the horizon of the *Olenelli* with the telson-like pygidia.

(4) Inferentially it appears probable that, if these *Olenelli* ever existed in Shropshire, their place is among the beds which are missing by reason of the unconformity.

(5) The beds (conglomerate and grits) immediately above the unconformity contain several species of *Paradoxides*, and should therefore be classed with the Middle Cambrian; but the evidence at present available is not sufficient to warrant a very close correlation with any of the horizons of the typical sections of Scandinavia.

(6) After passing a considerable interval of unexplored ground, we find a series of gritty flags with a fauna characterized by *Paradoxides davidis* and containing a number of brachiopods which, taken together, indicate a high horizon in the Middle Cambrian. These flags are succeeded above, with apparently complete conformity, by a series of shales in which occurs a form almost

---

[1] Geol. Mag. dec. 3, vol. viii (1891) p. 532.

[2] Rep. Brit. Assoc. 1910 (Sheffield) pp. 113–22, and MS. Rep. Brit. Assoc. 1911 (Portsmouth).

identical with *Orthis (Orusia) lenticularis* Wahlenberg, suggesting the incoming of an Upper Cambrian fauna.

(7) In close association with the flags yielding *P. davidis*, and only a little lower in the sequence, a species of *Paradoxides* with very elongated eye-lobes (*P. rugulosus* Corda) is found. It is therefore unsafe to infer that a *Paradoxides* with a long eye-lobe necessarily indicates a low horizon.

I hardly know how I can adequately express my indebtedness to Dr. Matley for all the trouble that he has taken in the identification of the brachiopoda associated with *Paradoxides davidis*. The specimens were numerous and indifferently preserved, and consequently a very great demand upon his leisure was entailed in order to go through them critically; then too he has had a great deal of tedious work in looking up the literature, and in writing and revising his descriptions of the various forms. For all of this I am most grateful, and I consider that I have been very fortunate in having been favoured with his co-operation.

I am also indebted to Mr. Philip Lake for much help, especially at the beginning of my studies of the Comley trilobites; it was a great advantage to me to have a safe road pointed out at the starting-point, by one who had travelled far in the same direction. To Mr. F. R. C. Reed and to Dr. G. F. Matthew my acknowledgments are gratefully made for their kindness in replying to my enquiries; and to Prof. Charles Lapworth there is an ever-increasing debt, that I can never hope to repay, for his continued kindly advice, encouragement and inspiration, in addition to his permission to publish my notes on his type-specimens of *Paradoxides groomii*.

APPENDIX.

NOTES on some of the BRACHIOPODA from the *Paradoxides*-Beds of Comley. *By* Dr. C. A. MATLEY.

Class BRACHIOPODA.

Order ATREMATA Beecher.

Family OBOLIDÆ King (emend.).

LINGULELLA cf. FERRUGINEA Salter. (Pl. XXVI, figs. 5–6 *b*.)

1867. Cf. *Lingulella ferruginea* et var. *ovalis* Salter, Q. J. G. S. vol. xxiii, p. 340 & figs. 1–3.

1868 & 1871. Cf. *Lingulella ferruginea* Davidson, Geol. Mag. vol. v, p. 306 & pl. xv, figs. 1–8; 'Monogr. Brit. Foss. Brach.' (Pal. Soc.) vol. iii, p. 336 & pl. xlix, figs. 32–35.

1876. Cf. *Lingulella (?)* sp. indet., Linnarsson, 'Brachiopoda of the *Paradoxides* Beds of Sweden' Bihang K. Svensk. Vetensk.-Akad. Handl. vol. iii, No. 12, p. 15 & pl. iii, figs. 27–28.
1883. Cf. *Lingulella ferruginea* Davidson, 'Monogr. Brit. Foss. Brach.' (Pal. Soc.) vol. v, pl. xvii, fig. 35.

Shell corneous, small, slightly convex, ovate; widest about a third from the front, length about one and a half times the breadth; broadly rounded in front; sides tapering to the beak, which in the pedicle-valve appears to have been acutely pointed. Numerous concentric growth-lines. Pedicle-slit narrow.

Dimensions.—Length = 4 millimetres, breadth = 2 to 2½ mm.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from a band of the Shoot-Rough-Road Flags with *Paradoxides davidis*, and also from a band with *Paradoxides rugulosus* at the top of the Shoot-Rough-Road Sandstone.

Note.—Three examples of this small *Lingulella* have been collected, and they agree fairly well with the Menevian species from St. David's, although the Shropshire form seems to be rather more acuminate at the beak. The *Lingulella (?)* figured by Linnarsson from the *Paradoxides-forchhammeri* strata of Sweden may be identical.

LINGULELLA (?) spp. indet. (Pl. XXVI, figs. 7–8 *b*.)

An imperfect single valve (fig. 7) has been obtained, which differs from the small *Lingulella* described above. It was found in the lower section on the Shoot-Rough Road, Comley, in the band of the Shoot-Rough-Road Flags yielding *Billingsella lindstrœmi*, var. *salopiensis*. The valve is nearly flat, the sides taper rapidly towards the beak, which is not preserved but appears to have been acuminate. The front is not preserved. Along the sides is a raised flat border or flange, about 0·5 millimetre wide. The shell-substance consists of several layers. The surface-ornamentation is not preserved, and the inner layers are smooth, except for faint indications of longitudinal striæ on one of them. Muscular markings not shown. Length = 10 millimetres or more; width = 6 mm.

Another form (figs. 8 *a* & 8 *b*), about 3 mm. long, rather broad, almost subpentagonal in outline, and possessing a concentrically striate exterior, occurs in the Shoot-Rough-Road Flags of the upper section, in association with *Acrotreta* aff. *socialis*. In shape it resembles, but is much smaller than, Linnarsson's *Lingulella (?) nathorsti* of the *Olenellus-kjerulfi* Zone at Andrarum in Scania.[1]

Another undetermined lingulelloid shell, a small oval form, occurs with *Lingulella* cf. *ferruginea* in the *Paradoxides-rugulosus* band of the Shoot-Rough-Road Sandstone of Excavation No. 23.

---

[1] Bihang K. Svensk. Vetensk.-Akad. Handl. vol. iii (1875–76) No. 12, p. 15 & pl. iii, figs. 29–30.

Order NEOTREMATA Beecher.

Family Acrotretidæ Schuchert.

Acrothele cf. granulata Linnarsson. (Pl. XXVI, figs. 9 *a* & 9 *b*.)

1876. *Acrothele granulata* Linnarsson, *op. jam cit.* Bihang K. Svensk. Vetensk.-Akad. Handl. vol. iii, No. 12, p. 24 & pl. iv, fig. 51 (and 52?).
1877 & 1883. Non *A. granulata* Swanston, App. to Proc. Belfast Nat. Field-Club ('Silurian Rocks of Co. Down'), pl. vii, fig. 20; and Davidson, 'Monogr. Brit. Foss. Brach.' (Pal. Soc.) vol. v, p. 214 & pl. xvi, figs. 29–30.
1908. *Acrothele* (*Redlichella*) *granulata*, Walcott, Smithsonian Misc. Coll. vol. liii, No. 1810, pp. 89–90.

The specimen figured [682] shows a partly-exfoliated fragment of the posterior portion of the pedicle-valve. The outermost layer where preserved shows under a strong lens a minute granulation, which at a little distance from the margin is arranged in wavy and irregular lines that cross the corrugations of growth at a very acute but variable angle. Close to the margin these wavy lines become more nearly parallel to the concentric lines of growth. The inner layers are smooth, and are pierced in the neighbourhood of the apex by the pedicle-tube. The valve when complete would be about 6½ millimetres wide, this being also the width of another (complete) valve from the same locality. Several more fragments showing the beautiful ornamentation of this species have also been obtained.

The specimens, though agreeing generally with Linnarsson's type in shape, size, and granulated character of the ornamentation, differ from the Swedish form in having the apex less excentric. In this respect they approach the closely-allied *A. coriacea* Linnarsson, of the *Paradoxides-forchhammeri* Zone. *A. granulata* is found in Sweden in the *P.-ölandicus* Beds, and in Warwickshire in the Lower Stockingford Beds (Purley Shales) near Nuneaton.[1]

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the band of the Shoot-Rough-Road Flags which yields *Acrotreta* aff. *socialis*. A fragmentary specimen [1116], showing similar granulated ornamentation, was obtained from the same flags of the lower section, in association with *Billingsella lindstrœmi*, var. *salopiensis*.

Acrotreta (Linnarssonia) sagittalis Salter. (Pl. XXVI, figs. 10 *a* & 10 *b*.)

1866. *Obolella sagittalis* and *Discina labiosa* Salter MS. Rep. Brit. Assoc. 1865 (Birmingham) p. 285.
1868 & 1871. *Obolella sagittalis* Davidson, Geol. Mag. vol. v, p. 309 & pl. xv, figs. 17–24; 'Monogr. Brit. Foss. Brach.' (Pal. Soc.) vol. iii, p. 339 & pl. l, figs. 1–14.
For further references see C. D. Walcott, Proc. U. S. Nat. Mus. No. 1299, vol. xxv (1903) p. 594.

Three examples of this species have been found in the lower section

---

[1] C. Lapworth & others, 'Geology of the Birmingham District' Proc. Geol. Assoc. vol. xv (1898–99) p. 346.

on the Shoot-Rough Road, Comley, in a band of the Shoot-Rough-Road Flags, associated with *Billingsella lindstrœmi*, var. *salopiensis*.

ACROTRETA aff. SOCIALIS von Seebach. (Pl. XXVI, figs. 11 *a*–11 *b*, 12, & 13 *a*–13 *b* [?].)

1865. *Acrotreta socialis* von Seebach, Zeitschr. Deutsch. Geol. Gesellsch. vol. xvii, p. 341 & pl. viii *a*, figs. 1–4.
1903. *Acrotreta socialis* and cf. *A. schmalensei* Walcott, Proc. U. S. Nat. Mus. No. 1299, vol. xxv, pp. 599 & 597.

Numerous specimens of a small *Acrotreta* have been obtained from the Shoot-Rough-Road Flags. The typical form has the pedicle-valve moderately elevated; the apex (bearing a minute foramen) excentric, but not overhanging the hinge-line; the false area well-defined, and showing a distinct pedicle-furrow. The surface is marked by growth-ridges, which in some specimens are rugose. The interior shows an apical callosity of moderate size with the foraminal tube well displayed. The brachial valve is slightly convex, and bears internally a strong median ridge and well-marked cardinal scars, with occasional traces of other scars.

This form agrees very well with the description of *A. socialis*, as re-defined by Dr. Walcott from specimens obtained from the *Paradoxides-ölandicus* Zone of the Island of Borgholm (Sweden); but our specimens are somewhat smaller than his, and in dimensions and in most other respects approximate very nearly to the form from the *Paradoxides-forchhammeri* Zone of Sweden assigned by Linnarsson also to von Seebach's species, but since separated by Dr. Walcott and described under the name of *A. schmalensei*.

Other forms of *Acrotreta* may possibly occur with the above, but I have been unable to separate them satisfactorily.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from a gritty band of the Shoot-Rough-Road Flags, 2 feet above the band containing *Paradoxides dav*

Order PROTREMATA Beecher.

Family BILLINGSELLIDÆ Schuchert.

BILLINGSELLA LINDSTRŒMI, var. SALOPIENSIS, nov. (Pl. XXVI, figs. 14 *a*–17 *c*.)

1876. Cf. *Orthis lindstrœmi* Linnarsson, 'Brachiopoda of the *Paradoxides* Beds of Sweden' Bihang K. Svensk. Vetensk.-Akad. Handl. vol. iii, No. 12, p. 10 & pl. i, figs. 1–8, pl. ii, figs. 9–12.
1905. Cf. *Billingsella lindstrœmi* Walcott, Proc. U. S. Nat. Mus. No. 1395, vol. xxviii, p. 238.

Shell biconvex, rotundo-subquadrate to subcircular in outline, wider than long, broadest at about the middle, cardinal angles rounded. The surface is covered with fine, rounded, radiating costæ increasing usually by interpolation, the interspaces being rounded and of about the same width as the costæ. Fine concentric,

usually inconspicuous, ridges cross the ribbing, and at intervals are more strongly marked. Forty to fifty, and sometimes even more, costæ may be counted around the margin of each valve.

Pedicle-valve moderately and uniformly convex, deeper than the brachial valve. Beak small; cardinal area triangular, bent away from the plane of the margin of the valve, and apparently striated parallel to the hinge-line. Delthyrium open in the specimens examined.

In the interior of the pedicle-valve the hinge-teeth are supported by dental plates which are continued to form a semicircular ridge enclosing a large concentrically-ridged muscular area around the umbo of the valve. This region is crossed by the vascular trunks which extend from the umbo for about two-thirds of the length of the valve. A low rounded elevation occupies the middle of the shell between the vascular trunks, but is not noticeable on the exterior.

Brachial valve slightly convex, with a low median sinus extending to the front. Beak small. Cardinal area narrow. A low rounded mesial ridge in the interior of the valve bears at its posterior extremity a simple rounded cardinal process. The widely-separated and divergent crura are short and stout. No chilidium appears to be present. Two pairs of elongated muscular impressions represent the places of attachment of the adductor muscle.

Dimensions.—The largest example collected (a brachial valve) measures 8 millimetres in length by 11 mm. in width, but the majority of the specimens average about 8 mm. in width.

Locality and horizon.—The lower section on the Shoot-Rough Road, Comley. Abundant as internal and external casts in a band of the Shoot-Rough-Road Flags, at or near the horizon of *Paradoxides davidis.*

Observations.—This variety appears to differ from the form described by Linnarsson from the *Paradoxides-forchhammeri* Zone of Sweden in the following respects:—

(*a*) The pedicle-valve is always deeper than the brachial, whereas, according to Linnarsson, the brachial valve of the Swedish form is the more convex.

(*b*) The ribbing is more regular, never exhibiting the wide interspaces figured by Linnarsson (*loc. cit.* pl. i. fig. 6 *c*).

(*c*) The Shropshire form is smaller, the dimensions being about two-thirds of those of the specimens described by Linnarsson.

In other respects the forms closely correspond.

The apparent absence of a deltidium makes the reference of this form to the genus *Billingsella* somewhat doubtful, although with this exception the species has all the essential features of the genotype *Orthis pepina* Hall (= *Orthis coloradoensis* Shumard).

BILLINGSELLA LINDSTRŒMI Linnrs., var. (Pl. XXVI, figs. 18 *a*–19 *b*.)

A very similar form is found associated with the above-described variety, but occurring less abundantly; and it is also found at a different section of the beds, which has not yielded the variety *salopiensis.* It differs from the last-named variety only in the

ribbing, the interspaces being occupied to a smaller extent by interpolated costæ. In this respect it comes nearer to Linnarsson's type of the species.

Intermediate forms occur, connecting this variety with that which I have named *salopiensis.*

Locality and horizon.—Both sections on the Shoot-Rough Road, in the Shoot-Rough-Road Flags: in the lower section associated with var. *salopiensis* and intermediate forms; in the upper section associated with *Acrotreta* aff. *socialis.*

BILLINGSELLA COBBOLDI, sp. nov. (Pl. XXVI, figs. 20 *a*–23.)

Shell semicircular in outline, biconvex, nearly twice as wide as long, widest at the hinge-line; cardinal angles rectangular, or nearly so. Valves ornamented with about ten or twelve principal strong rounded ribs. Additional ribs appear by interpolation at various distances from the beaks, so that around the margin of each valve some fifteen to eighteen ribs may generally be counted. Concentric lines of growth indent the ribs at close intervals.

Pedicle-valve gently convex, with a very slight depression along the middle. Area narrow, with small delthyrium; beak incurved; umbonal cavity small; hinge-teeth small, divergent, supported by small dental plates. Ribbing well marked in the interior of the valve, but muscular impressions not shown.

Brachial valve nearly flat. Area very narrow; beak small; cardinal process simple; muscular impressions not defined.

Dimensions.—Length = 9 to 10 millimetres; width = 16 to 17 mm.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the main mass of the Shoot-Rough-Road Flags, about 4 feet below the *Paradoxides-davidis* band.

Observations.—Five valves of this species, in the condition of internal and external casts, have been obtained by Mr. Cobbold. The British species which it most closely resembles is *Orthis hicksii* Salter (Davidson) from the Menevian Beds of St. David's.[1] The Shropshire form is, however, more transverse, the pedicle-valve less elevated, the cardinal area lower, and the umbonal cavity smaller. Its dimensions, too, are greater than those given by Davidson for *O. hicksii.* The species also approaches a form found in the *Paradoxides-forchhammeri* Zone of Sweden, which was originally described by Linnarsson[2] as *Orthis* aff. *hicksii* and subsequently designated by Dr. Walcott[3] *Billingsella exporrecta* var. *rugosicostata.*

The generic position of this fossil is somewhat doubtful, as the specimens do not exhibit the convex deltidium characteristic of the genus *Billingsella.*

---

[1] See T. Davidson, 'Monogr. Brit. Foss. Brach.' (Pal. Soc.) vol. iii (1869) p. 230 & pl. xxxiii, figs. 13–16; and Suppl. *ibid.* vol. v (1882–84) p. 184.

[2] *Op. jam cit.* Bihang K. Svensk. Vetensk.-Akad. Handl. vol. iii (1875–76) No. 12, p. 13 & pl. iii, figs. 22–23.

[3] Proc. U.S. Nat. Mus. No. 1395, vol. xxviii (1905) p. 236.

ORTHIS (ORUSIA) cf. LENTICULARIS Wahlenberg. (Pl. XXVI, figs. 24–26.)

Cf. *Orthis* (*Orusia*) *lenticularis* Walcott, Proc. U. S. Nat. Mus. No. 1395, vol. xxviii (1905) p. 273, where numerous references to earlier authors will be found quoted.

This species occurs as casts in the Shoot-Rough-Road Shales, in a micaceous shaly sandstone. Owing to the relative coarseness of the matrix, the surface-characters are poorly preserved, yet sufficiently to indicate that the ribbing of the shell was rather bold and was crossed by strong concentric lines of growth. Both valves are moderately convex, the pedicle-valve slightly more so than the brachial, the former having an obscure fold (?) and the latter a well-marked triangular sinus.

The majority of the specimens from the lower section on the Shoot-Rough Road, Comley, are quite small, about 2 to 2½ millimetres long by 3 to 3½ mm. in width. They are distinctly smaller than the specimens obtained from the Dolgelly Beds of North Wales. Further examples, from a rottenstone band in similar shales in the field north of the same spot, at a horizon perhaps rather higher than that of the lower section, are larger, ranging up to 6½ millimetres in width.

The imperfect preservation of these shells, as also their small size, renders their specific correspondence with the Dolgelly form a matter of uncertainty. *Orthis lenticularis* is found in North Wales, Sweden, Norway, and North and South America, and is characteristic of the *Peltura* Fauna of the Upper Cambrian. The specimens here described may belong to a lower zone.

ORTHIS? sp. (Pl. XXVI, figs. 27 *a* & 27 *b*.)

The only specimen found consists of a fragment of a nearly-flat valve, covered with numerous rounded costæ separated by narrower rounded interspaces and crossed at intervals by imbricating growth-lines. Though too incomplete for identification, it differs from all other known species of British Cambrian brachiopoda.

Locality and horizon.—The upper section on the Shoot-Rough Road, Comley; from the main mass of the Shoot-Rough-Road Flags, in the same bed as *Billingsella cobboldi*, about 4 feet below the band yielding *Paradoxides davidis*.

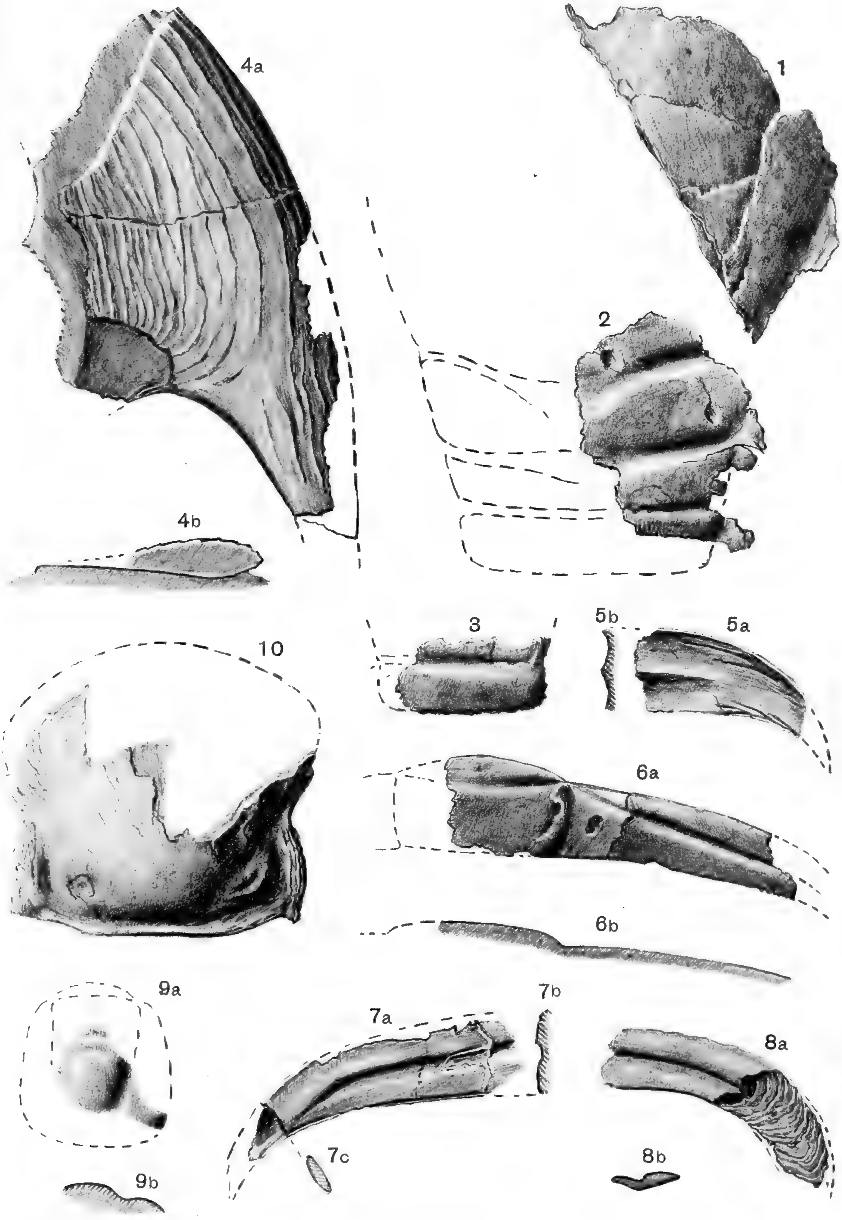
EXPLANATION OF PLATES XXIII–XXVI.

PLATE XXIII.

Paradoxides groomii Lapw. (See p. 283.)

[All the figures are of the natural size.]

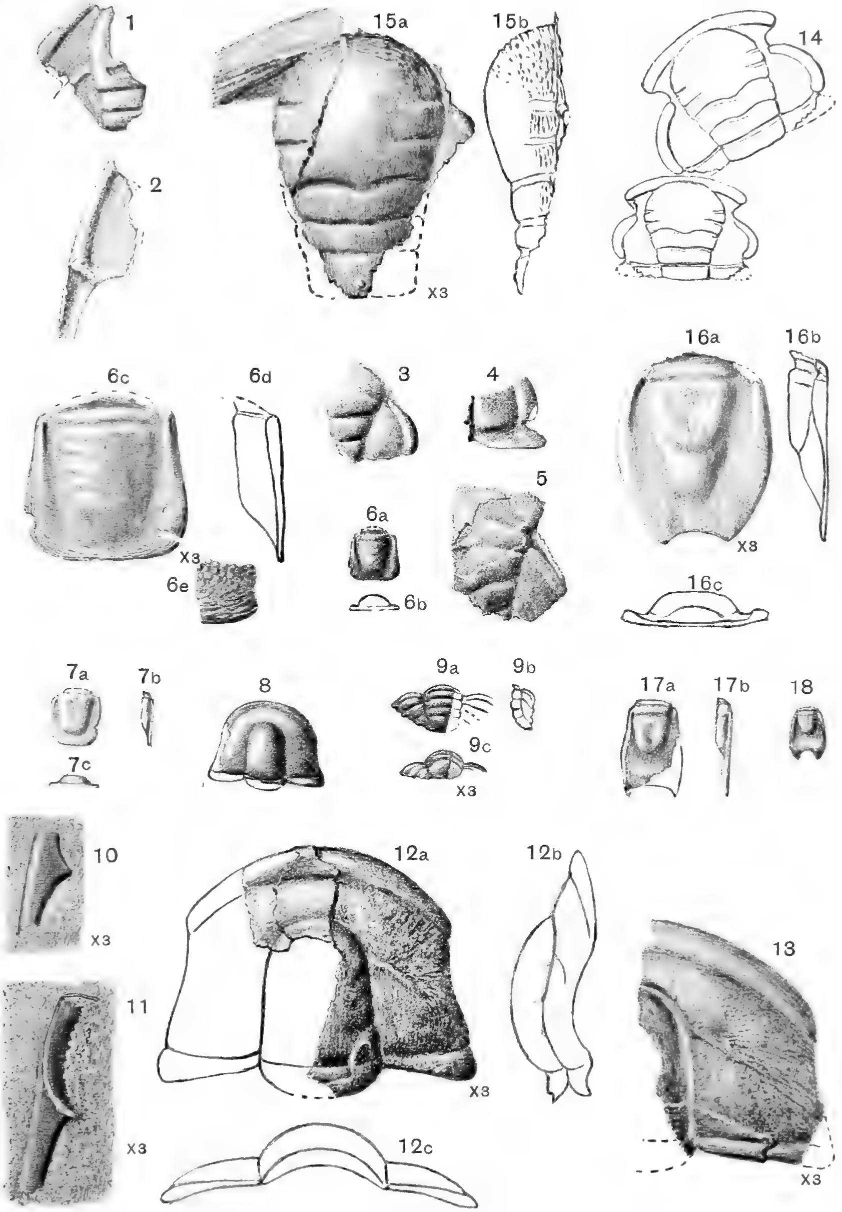
Fig. 1. Part of dome of glabella [A_1].
2. Part of glabella showing furrows [A_2].
3. Occipital ring [B_7].
4. Free cheek [D_1]: *a*, under side; *b*, section at the wide end.
5. External cast of the tip of one of the anterior pleuræ [A_7]: *a*, concave view; *b*, sectional view.



E. S. C., del.

Bemrose Ltd., Collo., Derby.

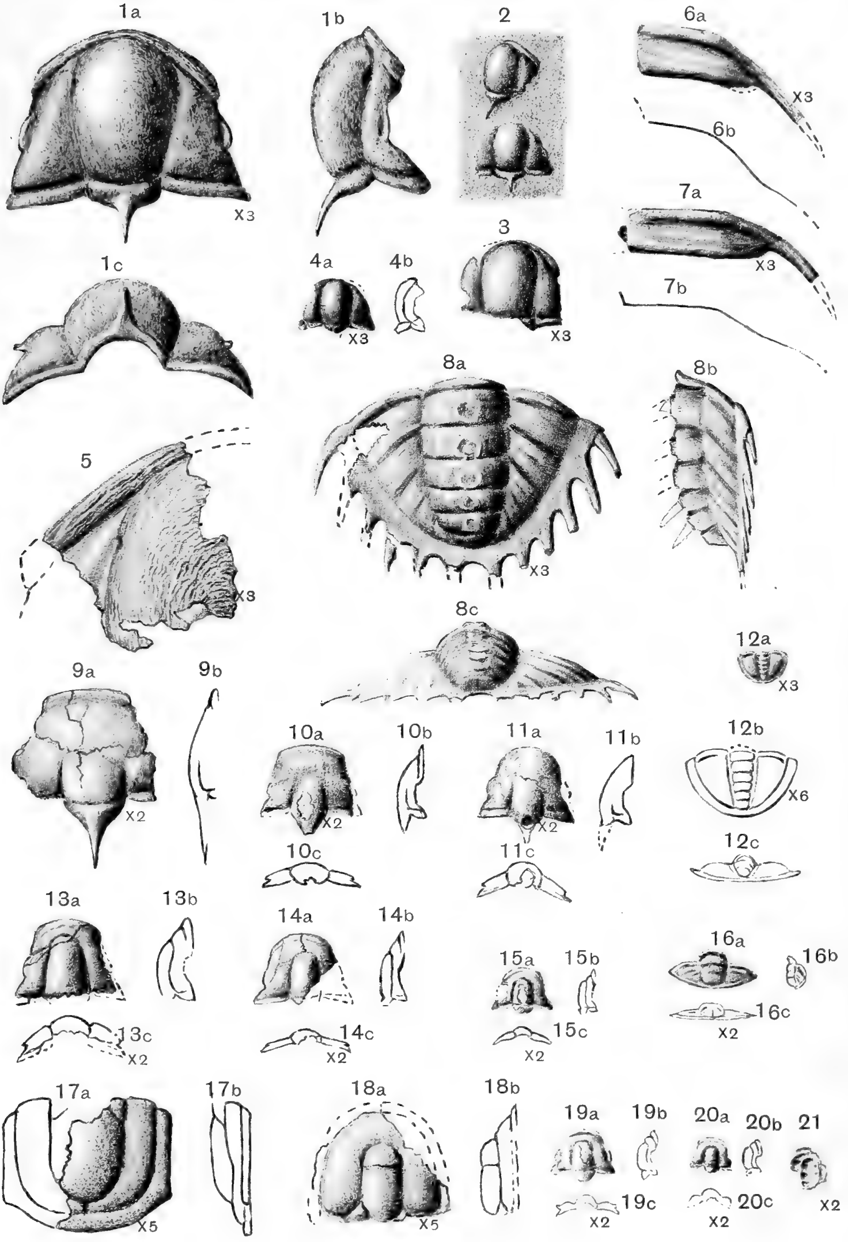
PARADOXIDES GROOMII, LAPWORTH, FROM COMLEY.



E. S. C., del.

Bemrose Ltd., Collo., Derby.

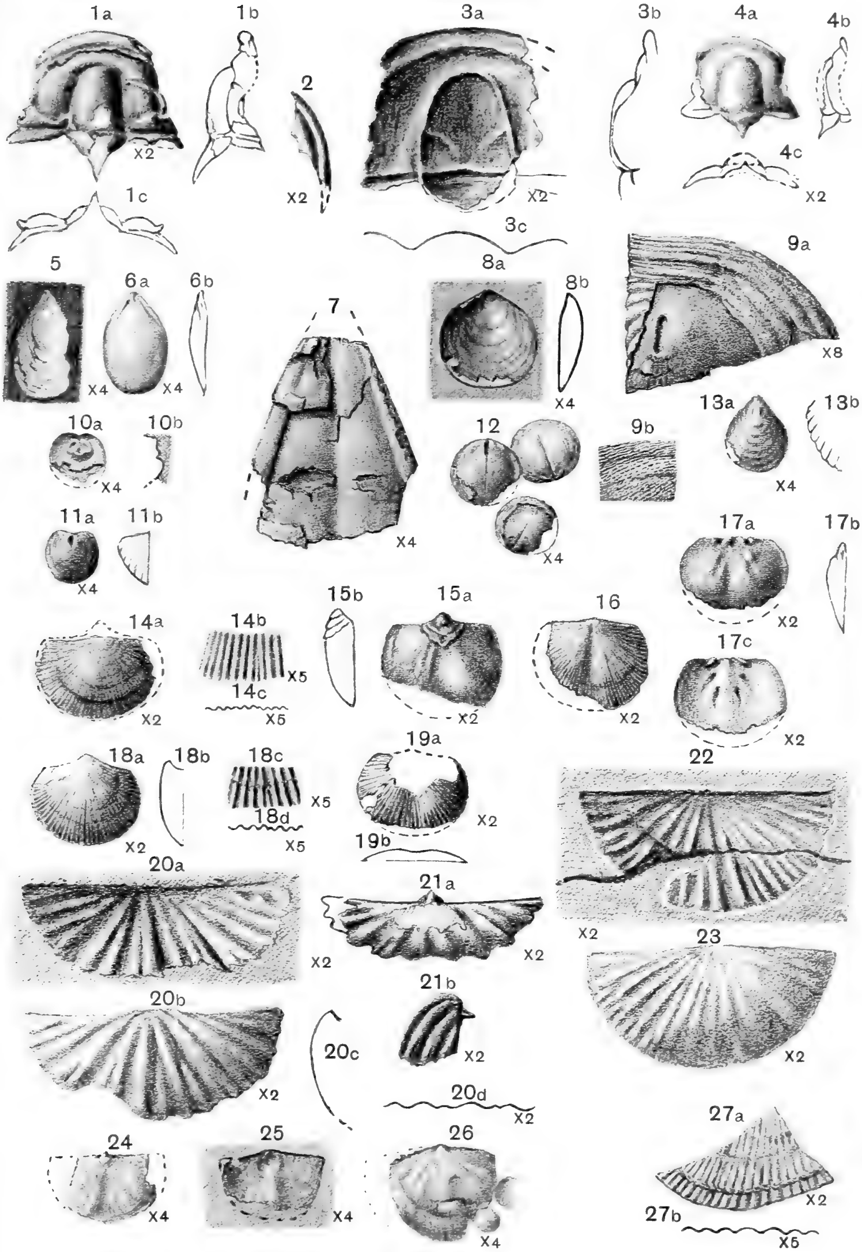
PARADOXIDES, ETC., FROM COMLEY.



E. S. C., del.

Bemrose Ltd., Collo. Derby.

CAMBRIAN TRILOBITES, FROM COMLEY.



E. S. C., del.

Bemrose Ltd., Collo., Derby.

CAMBRIAN TRILOBITES AND BRACHIOPODS FROM COMLEY.

Fig. 6. Thoracic segment [1307]: *a*, seen from above; *b*, section transverse to the thorax.
7. Median pleura [B_{12}]: *a*, seen from above; *b*, section near the middle of the length of the pleura; *c*, cross-section at the fracture.
8. One of the posterior pleuræ [1308]: *a*, seen from above; *b*, cross-section at the fracture.
9. Part of pygidium [A_5]: *a*, seen from above; *b*, transverse section. The posterior rounded outline is added from another specimen [A_6], the anterior margins are hypothetical.
10. Hypostoma, cast of interior [B_1]. The narrow posterior border is missing in the specimen, but appears in the external cast [C_1], which also shows the length along the axial line.

[Except figs. 6 and 8, all the specimens are in the Lapworth Collection.]

PLATE XXIV.

[Where no degree of enlargement is stated, the figures are of the natural size.]

Paradoxides sp. indet. No. 1. Comley Quarry. (See p. 285.)

Fig. 1. Part of glabella and front [1317 *a*].
2. Free cheek [A 470, H. C. B., P_1], Mr. Beasley's Collection.

Paradoxides sp. indet. No. 2. Comley Quarry. (See p. 285.)

Fig. 3. Part of glabella and fixed cheek [1314].
4. Fixed cheek and postero-lateral border [1307 *a*].
5. Part of glabella and fixed cheek [1317 *b*].
6. Pygidium [1171]: *a*, seen from above; *b*, from behind; *c*, from above, × 3; *d*, from the side, × 3; *e*, portion of posterior border much enlarged.

Paradoxides sp. indet. No. 3. Comley Quarry. (See p. 285.)

Fig. 7. Pygidium, Lapworth Collection: *a*, seen from above; *b*, from the side; *c*, from behind.

Conocoryphe emarginata Linnrs., var. *longifrons*, nov. Comley Quarry.

Fig. 8. Cranidium, seen from above [1317 *c*]. (See p. 286.)
9. Pygidium, probably of this species [A 470, H. C. B., C_1]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 3. Drawn from a plasticine mould of an external cast in Mr. Beasley's Collection.
10. Free cheek, referred with doubt to this species [1344], × 3.
11. Another specimen, seen from below [1345], × 3.
12. Internal cast of cranidium [204]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 3.
13. Internal cast of front and fixed cheek [1341], × 3. This represents the specimen as viewed from a direction normal to its transverse curvature, and not from above the complete cranidium. The cheek appears therefore proportionately wider than in the previous figure.

Paradoxides rugulosus Corda. Shoot-Rough-Road Sandstone, Comley.

Fig. 14. Outline of two very fragile internal casts of cranidia [1180]; the specimen is now much damaged. (See p. 286.)
15. Glabella and front [1073]: *a*, seen from above; *b*, from the side; both × 3.
16. Pygidium [1082]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 3.

Paradoxides davidis Salt. Shoot-Rough-Road Flags, Comley. (See p. 285.)

Fig. 17. Pygidium [319]: *a*, seen from above; *b*, from the side.
18. Pygidium, younger form [321]; seen from above.

Plate XXV.

Dorypyge lakei, sp. nov. Comley Quarry. (See p. 287.)

Fig. 1. Cranidium restored, from specimen [1163] fig. 2: *a*, seen from above; *b*, from the side; *c*, from behind; all × 3.
2. Two cranidia [1163], natural size.
3. A smaller cranidium, with variation in the shape of the glabella [184], × 3.
4. The smallest cranidium found [185]: *a*, seen from above; *b*, from the side; both × 3.
5. Part of a much bigger cranidium [1171] showing surface-markings, × 3.
6. One of the anterior (?) pleuræ [1332]: *a*, seen from above; *b*, sectional view; both × 3.
7. One of the posterior (?) pleuræ [1337]: *a*, seen from above; *b*, sectional view; both × 3.
8. Pygidium [181]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 3. The spines at the posterior end of the axial lobe are restored from another specimen [184].

Agraulos (?) holocephalus Matthew. Shoot-Rough-Road Flags, Comley.

Fig. 9. Cranidium much crushed [362]: *a*, seen from above; *b*, from the side both × 2. (See p. 292.)
10. Smaller cranidium, less crushed [361]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2.
11. Small cranidium, showing full convexity [360]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2.

Microdiscus sp. Cf. *M. punctatus* Salter. (See p. 292.)

Fig. 12. Pygidium: *a*, one of a group of internal casts [1297], × 3; *b*, outline diagram, × 6; *c*, the same seen from behind, × 6.

Agraulos sp., cf. *Arionellus quadrangularis* Whitfield. Shoot-Rough-Road Flags, Comley. (See p. 292.)

Fig. 13. Cranidium showing convexity [371]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2.
14. Cranidium flattened [370]: *a*, seen from above; *b*, from the side *c*, from behind; all × 2.
15. Cranidium, much smaller, with a more cylindrical glabella and more strongly marked marginal rim, referred to this species on account of the form of the cheeks as seen from behind [369]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2.

Agraulos (?) holocephalus Matthew? Shoot-Rough-Road Flags, Comley.

Fig. 16. Pygidium associated with the two previous species [376]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2. (See p. 292.)

Agnostus fallax Linnarsson. Shoot-Rough-Road Flags, Comley. (See p. 291.)

Fig. 17. Pygidium [346]: *a*, seen from above; *b*, from the side; both × 5.
18. Cephalon [344]: *a*, seen from above; *b*, from the side; both × 5.

Ptychoparia (Liostracus) ? dubia, sp. nov. Shoot-Rough-Road Flags, Comley. (See p. 295.)

Fig. 19. Cranidium, exterior [365]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2.
20. Cranidium, exterior [368]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2.
21. Cranidium, interior [366], showing glabellar grooves and ocular ridge, × 2.

PLATE XXVI.

Ptychoparia (Liostracus) pulchella, sp. nov. Shoot-Rough-Road Flags, Comley. (See p. 293.)

Fig. 1. Cranidium [353]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2.
2. Free cheek [372], referred with reserve to this species; × 2.

Ptychoparia (Liostracus) sp. indet. Shoot-Rough-Road Flags, Comley.

Fig. 3. Imperfect cranidium [1113], the only specimen known: *a*, seen from above; *b*, from the side; *c*, section across cheeks and glabella; all × 2. (See p. 295.)

Ptychoparia (Liostracus) sp. indet. Hill-House Grits, Comley. (See p. 294.)

Fig. 4. Imperfect cranidium [100]: *a*, seen from above; *b*, from the side; *c*, from behind; all × 2.

Brachiopoda.

Lingulella cf. *ferruginea* Salter. (See p. 300.)

Fig. 5. Interior of pedicle-valve, somewhat exfoliated [625], × 4.
6. Pedicle-valve, same individual [624]: *a*, internal cast; *b*, longitudinal section; both × 4.

Lingulella spp. indet. (See p. 301.)

Fig. 7. Partly exfoliated fragment [1033], × 4.
8. *a*, interior of a brachial valve [710]; *b*, longitudinal section; both × 4.

Acrothele cf. *granulata* Linnarsson. (See p. 302.)

Fig. 9. *a*, fragment of pedicle-valve [682], × 8; *b*, surface-granulation, greatly enlarged.

Acrotreta (Linnarssonia) sagittalis Salter. (See p. 302.)

Fig. 10. Pedicle-valve [705]: *a*, interior; *b*, longitudinal section; both × 4.

Acrotreta aff. *socialis* Linnarsson. (See p. 303.)

Fig. 11. Pedicle-valve [1025]: *a*, exterior; *b*, side view; both × 4.
12. Group of three brachial valves [690], × 4.

Acrotreta aff. *socialis* Linnarsson? (See p. 303.)

Fig. 13. Pedicle-valve [637]: *a*, exterior; *b*, side view; both × 4.

Billingsella lindstrœmi Linnarsson, var. *salopiensis*, nov. (See p. 303.)

Fig. 14. Pedicle-valve [1022]: *a*, exterior, × 2; *b*, surface, × 5; *c*, section of costæ, × 5.
15. Pedicle-valve [1008]: *a*, internal cast; *b*, side view; both × 2.
16. Brachial valve [1028]: exterior, × 2.
17. Brachial valve [1151]: *a*, internal cast; *b*, longitudinal section; *c*, interior from a plasticine mould; all × 2.

Billingsella lindstrœmi Linnarsson, var. (See p. 304.)

Fig. 18. Pedicle-valve [671]: *a*, exterior; *b*, longitudinal section; both × 2; *c*, surface, × 5; *d*, section of costæ, × 5.
19. Brachial valve [665]: *a*, exterior; *b*, transverse section; both × 2.

Billingsella cobboldi, sp. nov. (See p. 305.)

Fig. 20. Pedicle-valve [1112]: *a*, external cast; *b*, exterior from a plasticine mould; *c*, longitudinal section; *d*, section of costæ; all × 2.
21. Pedicle-valve [652]: *a*, posterior view of internal cast; *b*, side view, restored about the umbo from a plasticine mould of the exterior; both × 2. [The specimen has been somewhat damaged since the figure was drawn.]
22. Brachial valve [654 & 653]: external cast, × 2.
23. Brachial valve, same individual [655]: internal cast, ribs somewhat damaged, × 2.

All the above brachiopoda are from the Shoot-Rough-Road Flags and Sandstone, Comley.

Orthis (Orusia) cf. *lenticularis* Wahlenberg. Shoot-Rough-Road Shales, Comley. (See p. 306.)

Fig. 24. Brachial valve, internal cast [601], × 4.
25. Pedicle-valve, external cast [614], × 4.
26. Pedicle-valve showing larger dimensions, internal cast [611], × 4.

Orthis ? sp. Shoot-Rough-Road Flags, Comley. (See p. 306,)

Fig. 27. *a*, exterior, from a plasticine mould of the external cast of a very slightly convex valve, × 2; *b*, section of costæ, × 5.

Discussion.

Dr. H. Lapworth, in expressing his sense of the value of the paper, remarked on the general importance (from the economic standpoint) of making trench-like excavations, such as those by means of which the Author had conducted his patient and detailed investigations.

Mr. T. H. Withers said that the Author was to be congratulated on having added a most valuable contribution to our knowledge of the fauna and succession of the Middle Cambrian beds in the neighbourhood of Comley. Perhaps the most interesting of the trilobites obtained by the Author was the form named *Dorypyge lakei*, since representatives of the genus *Dorypyge* were also found in the Middle Cambrian of North America, Bornholm (Baltic), and China. Judging from the trilobite fauna described by the Author, the speaker was of opinion that it showed closer affinity to that of Bornholm than to that of North America, and he would be glad to know whether the Author concurred in this view.

Miss Raisin had been much interested in the paper, all the more that, owing to the kindness of the Author in sending her instructions, she had been able to see a little of the sections described, when she was recently in Shropshire on an expedition with her students. She would like to ask a question with regard to the section at Robin's Tump. It was evident that, in the southern part, the limestone pebbles would belong to the grit laid down after the interval of time marked by the unconformity. But what exactly would be the position and age of the original limestone-band—the 'rib of limestone' in the diagram? It was extremely interesting to have an example of a limestone in these Cambrian

rocks, the absence of calcareous bands being generally a feature of these strata in British areas.

Mr. J. F. N. Green thought that the Author's researches would throw much light on the succession in the South Welsh Cambrian. In particular, the unconformity demonstrated in Shropshire might prove to be of wide extent, as some years ago the speaker had been led to suspect the existence of a non-sequence in the middle of the Paradoxidian beds of Pembrokeshire.

The Author briefly thanked the Fellows for their reception of his paper. He was particularly interested to hear of the signs of unconformity, mentioned by Mr. Green as occurring at the base of the Menevian in South Wales. In reply to Miss Raisin, he said that the lower sandstones of Comley were not absolutely barren, but contained calcareous bands that were fossiliferous. He took the opportunity of emphasizing the fact that these lower beds had been deeply eroded prior to the deposition of the Paradoxidian sediments, the trilobites of which must have inhabited a shore among pebbles and boulders containing the previously fossilized *Protolenus-Callavia* Fauna. The interval might be compared with that between the Pliocene and the present time. Referring to the remarks of Mr. Withers, the Author agreed that the *Paradoxides* faunas of Comley are closely related to those of Scandinavia; while the fauna of the Lower Cambrian has stronger affinities with that of North America.

11. *The* STRATIGRAPHY *and* TECTONICS *of the* PERMIAN *of* DURHAM (NORTHERN AREA). By DAVID WOOLACOTT, D.Sc., F.G.S. (Read April 5th, 1911.)

[Abstract.]

THE Permian strata of Durham and Northumberland lie unconformably on a basin of the Coal Measures. They can be divided as follows:—

(4) Upper red beds, with salt and thin fossiliferous magnesian limestones (only exposed in the south of Durham). 300 feet.

(3) The Magnesian Limestone.

(*a*) Upper.

1. Yellow bedded limestone of Roker. 100 feet.
2. The concretionary limestone of Fulwell and Marsden—a series of concretionary and non-concretionary limestones and marls. 150 to 250 feet.
3. The Flexible Limestone. 10 to 12 feet.

(*b*) Middle.

Unbedded (as a rule), highly fossiliferous (often) limestone of Claxheugh, Tunstall, etc. Forms a ridge of high ground, and reaches a thickness of 300 feet. Often brecciated and entirely changed in character—rendered more calcareous and fossils obliterated.	replaced on the east by	Bedded yellow, non-fossiliferous limestones of the northern end of Marsden Bay and the coast from Hendon to Seaham Harbour. Often highly brecciated 150 feet.

(*c*) Lower. Bedded brown limestones of Frenchman's Bay, Houghton etc. Upper beds often disturbed. 40 to 200 feet.

(2) The Marl Slate. 3 feet.

(1) The Yellow Sands, from 0 to 150 feet.

These beds, which vary much in thickness, lie in North Durham in the general form of a syncline beneath Sunderland.

The unfossiliferous Yellow Sands are probably a deltaic formation reassorted by wind, the other beds being the result of deposition in an inland sea undergoing desiccation. The magnesium carbonate existed in the waters of the sea, and was either deposited along with the calcium carbonate, or introduced by seepage when the beds were being laid down.

Great changes in the amount and distribution of these carbonates have, however, taken place since deposition. The cellular structures that occur in the limestone can be classified as follows:—(1) Concretionary-cellular; (2) negative breccia; (3) solution-cavities; and (4) fractured cellular. Most of them have been produced by the leaching-out of the magnesium carbonate (dedolomitization), or of both that and calcium carbonate. In some cases the rock

has been rendered crystalline, as well as more calcareous, and the fossils have been obliterated. They do not afford any proof that the rock has been dolomitized subsequent to deposition. The percentage of calcium carbonate is sometimes over 99, while that of magnesium carbonate is occasionally as much as 50.

The fauna of the Magnesian Limestone is very restricted (about 140 species) and most peculiarly distributed. The marked palæontological features are the profusion of individuals in the Middle Fossiliferous Limestone (which appears to have formed a shell-bank in the Middle Magnesian-Limestone sea) and their sudden disappearance in the Upper Limestone. No corals, echinoderms, polyzoa, brachiopods, or cephalopods have ever been found above the top of the Middle Fossiliferous division: only a few fishes, gastropods, lamellibranchs, entomostraca, and foraminifera occurring in the Upper beds. The Lower and Middle Fossiliferous Limestones are marked by the presence of *Productus horridus* Sow. Fish-remains occur at two horizons: namely, the Marl Slate and the Flexible Limestone, and the beds above these deposits.

The Brecciated Beds, which occur at various horizons, chiefly however in the two Middle divisions, constitute the most marked tectonic feature of the Magnesian Limestone of the area. They have been produced by thrusting, which brought about a decrease in the lateral extension of the Permian. Associated with the breccias are other proofs of thrusting: (1) Thrust- or shear-planes; (2) disturbed and displaced masses of Lower Limestone; (3) intruded breccias; (4) slickensided and grooved, horizontal and vertical surfaces; (5) cleavage; (6) folding, both on a local and on a general scale; (7) buckling, thickening, and squeezing-out of beds; (8) phacoidal and other structures; and (9) fissuring. The main thrust at Marsden appears to have acted from a few degrees south of east to a few degrees north of west; there are, however, distinct evidences of movement from other directions in different parts of the district. Experiments, made on the compressive strength of the rocks affected by the thrust at Marsden, indicate that the thrusting reached a maximum of about 300 tons per square foot. Observations made by Mr. S. R. Haselhurst, M.Sc., in the Cullercoats area seem to prove that the thrusting occurred later than the post-Permian movement of the Ninety-Fathom Dyke—some faulting in the area is, however, later than the thrusting—, and it appears evident that the shattering of the strata was produced prior to the pre-Glacial era of denudation. It may have been connected with the Miocene movements that produced such marked changes in the physiography of Britain.

Discussion.

The Chairman (Dr. C. W. Andrews) suggested that perhaps comparison of the Permian dolomitic limestones with those of the post-Miocene raised reefs of Christmas Island (Indian Ocean) might help to throw some light on the question of dolomitization.

Prof. E. J. Garwood congratulated the Author on the care and perseverance of which he had given proof in working out the Permian geology of an area with which the speaker had been familiar from his childhood. He was glad that the Author had confirmed his own views regarding the original character of the magnesium carbonate present in these beds. He asked whether the Author had been able to determine the general direction of the thrusting over the area to the south of the Tyne Valley, and whether the movement which produced it could be shown to be connected with the thrust described by Prof. Lebour & Dr. Smythe in the Coal Measures farther north; whether any approximate date could be assigned to these movements; and whether they belonged to more than one period. The speaker referred to the difficulties in explaining the V-shaped breccia-gashes, and asked the Author whether he accounted for the uninterrupted character of the overlying bedding-planes on the view that these had been thrust over the gashes as a whole; were the nether surfaces of these overlying beds striated in the manner which the Author had described elsewhere? He agreed with the Author that the marly magnesian matrix had been removed from the beds in which the cellular structure was developed, but thought that this may often have taken place by the mechanical action of water. For this reason he deprecated the use of the term 'dedolomitization' for that process, as the term had now come into general use for cases where the magnesium was not removed, but had entered into fresh combinations.

Mr. E. E. L. Dixon had listened with much interest to the Author's discussion of several points of general importance. He inquired what precisely was the agency that the Author supposed to have deprived a 'dedolomitized' limestone of its magnesium. Under conditions of ordinary weathering a dolomite is undoubtedly more resistant than a limestone, unless, as in the case of some of the dolomites in the Carboniferous Limestone of South Wales, the dissolution of a slight amount of interstitial calcite releases a considerable quantity of dolomite in the form of loose crystals or grains, and enables them to be washed away mechanically. The disappearance of everything, including insoluble impurities, from the cavities in the 'dedolomitized' limestones would seem to demand some such action. Another point raised was the origin of the dolomite. What was the evidence that any of it was an original, chemical precipitate?

The speaker was anxious to hear whether the Author considered that all the masses of breccia in Marsden Bay had originated in earth-movements. Prof. Lebour's explanation—that some of them, the 'breccia-gashes,' had been caused by collapse of material into cavities formed by solution in the limestone—had led the speaker to apply the term 'gash-breccia' to large masses of breccia, up to several hundred yards across apparently, in the Carboniferous Limestone of South Wales. These had undoubtedly originated by collapse into solution-cavities in the heart of the pre-Triassic Armorican mountain-chain; and it would be decidedly awkward

if it were now found that the original 'breccia-gashes' had had an entirely different origin.

Mr. G. W. LAMPLUGH recalled the overthrust in the Chalk on the north side of Flamborough Head, which resembled some of the disturbances described by the Author, and deserved consideration in discussing the age of earth-movements on the north-east coast. He further mentioned that a succession comparable to that of Durham could be traced in the Magnesian Limestone Series of North-East Derbyshire; but the subdivisions in the two districts may represent equivalence of phase, without exact equivalence of time. He enquired whether the Author had observed any dome-like structures among the more massive limestones of Durham, as such structures were conspicuous in parts of Eastern Derbyshire and appeared there to be due to conditions of deposition.

The AUTHOR thanked the Fellows present for the manner in which they had received his paper. He also expressed his thanks to Mr. S. R. Haselhurst, M.Sc., for making the model of the district shown, and to Mr. C. T. Trechmann, B.Sc., for some of the specimens of fossils lying on the table. He agreed with Prof. Garwood's suggestion that sometimes the magnesium carbonate may have been removed by the mechanical action of water; but some of the cellular forms described had certainly been produced by chemical action. In reply to Mr. Dixon, he stated that, under certain conditions of temperature and pressure, magnesium carbonate (in the presence of calcium carbonate) was the most soluble of the two salts. He emphasized the need for a thorough study of the relative solubilities of these two carbonates in presence of one another, and of such other substances as must have existed in the Permian sea. Both these speakers had referred to the 'breccia-gashes': he was convinced that the vertical 'breccia-fissures' had been produced at the end of the period of thrusting; but some of the triangular 'breccia-gashes' may have been caused by the falling-in of caverns, formed by the mechanical removal of softer beds or by their solution.

The thrusting in the Permian appeared to be directed towards a central area; the accentuation of the Coal-Measure basin of Northumberland and Durham beneath East Durham, as also the synclinal form of the Permian strata in the same area, was probably produced by it. That it was connected with some general movement of the North-of-England strata, as suggested by Prof. Garwood, seemed certain. The Author regarded it as having taken place between the Cretaceous and the Miocene Periods.

12. Faunal Horizons *in the* Bristol Coalfield.

By Herbert Bolton, F.R.S.E., F.G.S., Curator of the Bristol Natural History Museum. (Read March 22nd, 1911.)

[Plate XXVII—Fossils.]

The Bristol Coalfield differs from the Midland and more northerly fields in the paucity of animal remains which have been discovered therein. Whereas the last-mentioned coalfields are capable of division by their faunas alone, the Bristol Coalfield, and the South Wales Coalfield, can hardly be so treated; and, for the same reason, no close correlation with the Midland and Northern Coalfields can be established, except by means of fossil plants and the general lithological agreement.

The Bristol Coalfield is largely covered by later rocks, surface-sections being rare. The search for evidences of a fauna has therefore to be carried on chiefly under ground, and among material brought to the surface in the course of mining operations.

By an examination of a measured section at the junction of the Millstone Grit and Lower Coal-Measures in the South Liberty Colliery at Bristol, I was able to demonstrate the existence of a marine fauna in these measures.[1] The same method has since been applied to the measures underlying the Bedminster Great Vein, and with successful results. It was shown in my former paper (*op. cit.* p. 448) that the Bedminster Great Vein was correlated by Handel Cossham with the Kingswood Great Vein, so that the measures examined have a development along the whole of the south-western side of the Bristol area.

With the guidance of the information obtained from the Ashton and Bedminster Series, and with the aid of a grant of £20 from the Royal Society, search has been prosecuted at as many collieries as possible throughout the Coalfield, and fair results have been accomplished. Evidence has been obtained of the existence of fossiliferous horizons at the following collieries:—

South Liberty,
Easton,
Hanham, } in Gloucestershire, and near or in Bristol.
Speedwell Deep,
Coalpit Heath,

Ludlows,
Middle Pit, } Radstock,
Tyning,
Wells Way,
Writhlington, } in Somerset.
Foxcote,
Dunkerton,
Newbury,
Mackintosh,

---

[1] Q. J. G. S. vol. lxiii (1907) pp. 445–69 & pl. xxx.

(1) South Liberty Colliery, Bedminster.

The shaft of this colliery passes through 100 feet of Trias at the surface, and penetrates the Lower Coal-Measures to a depth of 1386 feet. A generalized section of the shaft is as follows:—

	Feet.	Feet.
To Bedminster Top Vein	630	630
To Bedminster Great Vein	120	750
To Toad Vein	396	1146
To Ashton Great Vein	240	1386

By the courtesy of the Directors of the Ashton Vale Coal & Iron Company, and of their manager, Mr. A. Fisher, from whom I have received every assistance, I was able to obtain the services of several miners, who cut out for me a measured section from the top of the Ashton Seam upwards to the Bedminster Great Vein.

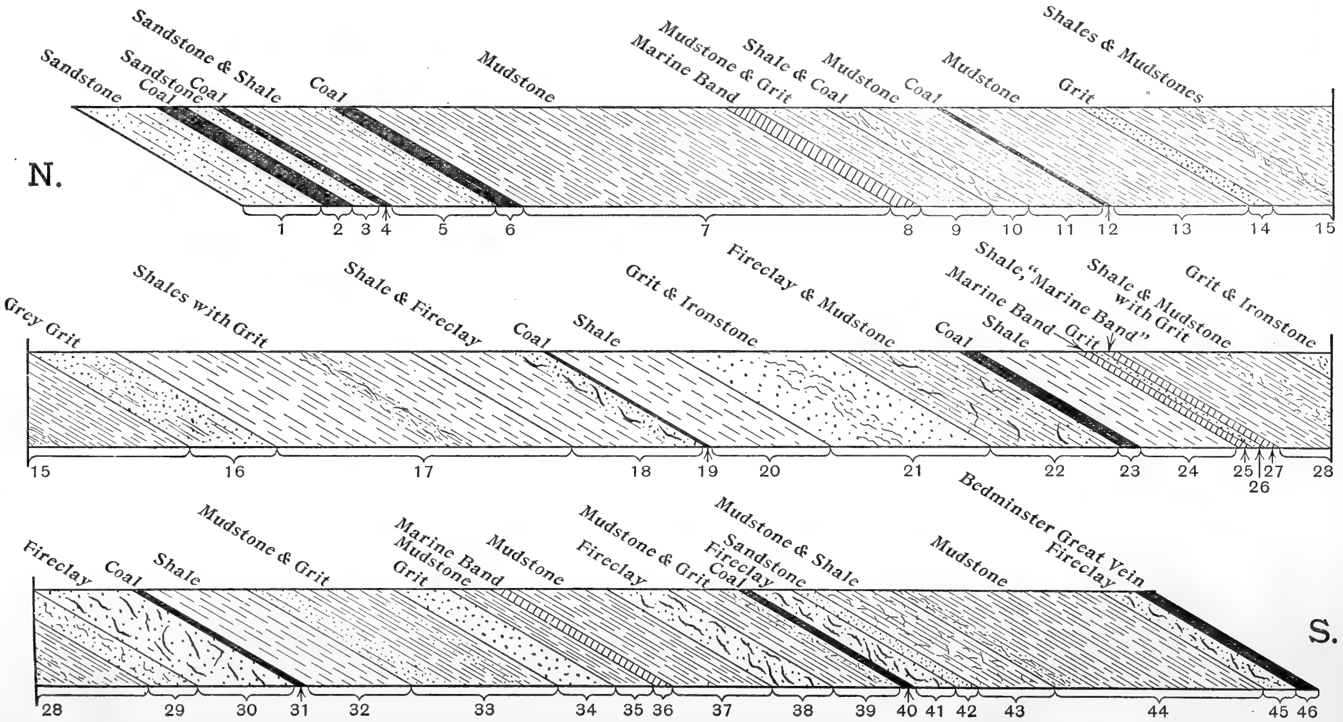
The material thus obtained was afterwards examined with the greatest detail. In all, 760 feet of shale, sandstone, etc. were cut out and worked over, but the results were disappointing. Four faunal horizons were determined, the suite of fossils in each being very small, and the fossils much reduced below the normal size of the species, except in the case of *Anthracomya.*

The detailed section cut out was as follows, the beds being arranged in descending order:—

Examined Section at South Liberty Colliery (in descending order).

			Thickness in feet	inches.
46. Bedminster Great Vein Massive well-bedded bituminous coal.			3	0
45. Dark grey fireclay, with small ironstone nodules and abundant Stigmarian rootlets			7	6
44. Mudstone, with a 3-inch band of cannel-like shale Lower part crushed.			42	9
43. Shale and mudstone. Dark grey, much slickensided and bearing traces of plants			15	6
42. Sandstone. Grey, micaceous, and current-bedded			5	3
41. Fireclay. Hard, compact, with ironstone nodules and Stigmarian rootlets			8	0
40. Coal. Soft and friable			3	2
39. Grey grit with mudstone, the former showing laminations of coaly matter, the latter bearing Stigmarian rootlets			14	9
38. Fireclay with rootlets			12	0
37. Mudstone, much slickensided and with rootlets			22	1
36. Black shale. 'Marine Band,' 'Horizon 4.' Much slickensided; yielding obscure plant-remains, also *Carbonicola* cf. *acuta* and *Anthracomya phillipsi*			3	6
35. Mudstone			8	0
34. Gritstone. Massive, well-bedded, full of calcite-veins and pyrite			10	6
33. Grits and mudstones.	Thickness in feet	inches.		
Dark-grey micaceous grit	6	0		
Micaceous mudstone with plant-remains	12	6		
Massive grit	1	10		
Mudstone	10	3	30	7
32. Black and grey shales, with Lepidodendroid twigs and leaves.			22	6

Section of the Bristol Lower Coal-Measures, from the Ashton Great Vein to the Bedminster Great Vein.
(Thickness of strata shown = 760 feet.) By T. J. Moss-Flower.



[*Section at South Liberty Colliery, cont.*]	*Thickness in feet*	*inches.*
31. Coal, much slickensided	1	10
30. Fireclay. Soft, grey, and much contorted, passing into hard shale below	20	2
29. Quartzose grit, with ironstone. A few traces of plant-remains	? 10	0
28. Shales and mudstones, with a band of quartzose grit. The upper 12 feet much like a fireclay	? 35	0
27. Shale. 'Marine Band,' 'Horizon 3.' Soft, dark grey, and well-bedded, containing ironstone nodules. Yields *Anthracomya lævis* var. *scotica, Pterinopecten papyraceus, Nucula oblonga, Estheria*, and *Bairdia (?)*	2	8
26. Grit. Micaceous and massive	2	0
25. Shale. 'Marine Band: Horizon 2.' Dark grey, well-bedded, containing ironstone nodules, *Neuropteris, Cordaites*, etc., *Anthracomya lævis* var. *scotica*, and *Naiadites elongata* ...	3	7
24. Shale. Micaceous and massively-bedded	21	0
23. Coal. Earthy and slickensided	3	8
22. Fireclay and mudstone: the former slickensided, the latter yielding obscure plant-remains	26	3
21. Gritstone, with nodular ironstone. Full of Stigmarian rootlets and coaly streaks	32	1
20. Black and grey shales. Micaceous, containing *Sphenopteris* and comminuted plant-remains	25	4
19. Coal. Bituminous and much slickensided	1	0
18. Fireclay, passing into shale below. Stigmarian rootlets abundant; contains ironstone nodules	27	1
17. Shales. Hard grey shale, with ironstone nodules. Contains *Annularia* and *Calamites*	61	4
16. Grey grit. Much slickensided	16	10
15. Shales and mudstones, partly crushed	44	7
14. Grit. Massive and well-bedded	5	4
13. Mudstone. Black and grey, containing ironstone nodules and many Stigmarian rootlets	29	5
12. Coal. Much iron-stained	1	0
11. Mudstone. Massive grey rock, with Stigmarian rootlets	15	10
10. Shale and coal. Mashed-up mass of rock, slickensided everywhere. The shale has all the appearance of a 'Marine Band' material	7	1
9. Mudstone and grit. Massively-bedded and micaceous	15	9
8. Black shale. 'Marine Band: Horizon 1.' A soft shale, easily breaking up, containing *Anthracomya lævis* var. *scotica, Carbonicola* sp., and insect-wings	4	11
7. Mudstones, with plant-remains	78	5
6. Coal, partly crushed	4	10
5. Sandstone and shale	22	0
4. Coal	2	6
3. Sandstone. Massive grey rock, with veins of calcite. Ironstone nodules are found in it occasionally	5	5
2. Coal. Soft, and slickensided everywhere	7	2
1. Sandstone. Dark-grey, fine-grained rock, with calcite-veins. Traces of plants	16	6
Ashton Great Vein.		
Total	759	8

The faunal horizons occur below the Bedminster Great Vein at depths (below it) of 134, 284, 286, and 637 feet, respectively. Several of the black shales met with possess the characters of marine-band shales, but no trace of fossils could be found. At a depth of 396 feet below the Bedminster Great Vein, occurs the Toad Vein;

and, while driving operations were being carried on in connexion with the latter, a small collection of fossils was obtained from the shales thrown out upon the waste-heap. I have not been able to localize the horizon.

Attention was also paid to the shales in the vicinity of the Bedminster Great Vein at the South Liberty Colliery, in the hope of finding a fossiliferous shale over the roof of this seam.

(2) Easton Colliery.

This colliery lies to the north and east of that of South Liberty, and has been sunk in Lower Coal-Measures, which here extend about 700 feet above the Bedminster Great Vein. From the spoil-heap of the colliery were obtained examples of *Carbonicola aquilina*, *Anthracomya phillipsi*, *Naiadites carinata*, and *Lingula mytiloides*. The black shale containing the two first-mentioned species was recognized by Mr. Staple, of Easton Colliery, as forming the roof of the Easton Great Vein, a seam which Godwin-Austen correlated with the Bedminster Great Vein.

Lingula mytiloides and *Naiadites carinata* occurred in a thick bed of black micaceous shale, the first-named species in great numbers. The shale was indeed a typical '*Lingula* Shale.' So far as I have been able to locate this deposit, it lies somewhere in the vicinity of what is known as the 'Five Coals' Seam, and at about 80 to 100 feet above the Easton Great Vein. The presence of numerous coprolites was noted, but no trace was found of fish-remains.

(3) Hanham Colliery.

This colliery lies on the eastern outskirts of Bristol, the shaft passing through a considerable thickness of the Pennant Grit into the upper portion of the Lower Coal-Measures. From the spoil-heap was obtained a black shale packed with hundreds of *Lingula mytiloides*. A fragment of the dentary of *Megalichthys pygmæus* was also found, and a large goniatite which broke up in course of extraction.

The *Lingula* Shale of this colliery is identical in all its features with that from Easton, but I have no information respecting the horizon at which it occurs. It is quite within the range of probability that the horizon may be higher in the series. Further information from this colliery is much wanted.

(4) Speedwell Deep Colliery, Kingswood.

This colliery lies within the boundaries of the city of Bristol as now defined, and has been sunk through the Kingswood Series of Lower Coal-Measures. One of the first seams passed through is the Doxall Seam, below which come the Lyalong, Old Road, Trough, Hole or Hard, Five Coals, Thurfer, Great, Giller's Inn, and Little Toad Seams.

From the spoil-heap of Speedwell Deep Colliery were obtained a few examples of *Anthracomya minima*, *A. lanceolata*, and

Naiadites elongata (?), all in a compact black shale. It is extremely likely that this shale came from the vicinity of the Little Toad Seam. Dr. Wheelton Hind has recorded the occurrence at this colliery of *Anthracomya phillipsi*, but the horizon was not determined.

Upper Coal-Measures of the Northern Portion of the Coalfield.

Examination of the spoil-heaps of collieries in which the Upper Series are worked has proved that several faunal horizons occur in the Upper Coal-Measures of the northern portion of the coalfield.

(5) Coalpit-Heath Colliery.

This colliery lies in the northern basin of the coalfield, being shut off from the larger Bristol portion by the Kingswood Anticline, which brings up the Pennant Grit and Lower Coal-Measures to the surface. The colliery is about equally distant from Mangotsfield on the south, and from Iron Acton on the north. Only four workable seams are present in the Upper Measures in this district, the lowest being the High Vein, which is reached at a depth of 624 feet in the shaft of Coalpit-Heath Colliery. The lower 152 feet of the shaft gave the following section:—

		Feet	*inches.*
Parkfield Series.	Hard Vein	2	3
	Strata	85	0
	Holly Bush	2	6
	Strata	58	0
	High Vein	5	0

The roof-shales of the High Vein yielded the following series of fossils:—*Anthracomya williamsoni*, *Naiadites elongata*, *Leaia leidyi* var. *salteriana*, *Bairdia* cf. *ampla*, *Bairdia* sp., and *Estheria* sp.

Lower Coal-Measures of the Vobster Area.

Two collieries opened in the 'Vobster and New Rock Series' yielded fossils, namely those of Newbury and Mackintosh. The Mackintosh pit, which is frequently spoken of by the miners as the 'Highbury,' lies to the south of Radstock, and is deeper than that of Newbury, two seams of the Vobster Series being worked at depths of 1242 and 1620 feet respectively. A dark compact shale from this colliery yielded ostracoda and a fragmentary valve of *Anthracomya (?)*.

(6) Newbury and Mackintosh Collieries.

The Newbury Colliery lies in the Coleford district, a few miles south of Radstock. The shaft goes down to a depth of about 720 feet, and near the bottom passes through the upper member (the Dungy Drift) of the Vobster Series. From the base of the shaft, a northern branch has been carried below and beyond the

shaft of the Luckington pit, intersecting the following seams of the New Rock Series:—

Firestone.
Great Course.
Strap.
Garden Course.
Warkey Course.
Thin Coal.
No. 1 Seam.
No. 2 Seam.
Thin Coal.

The upper part of the Newbury shaft passes through two seams of the Vobster Series, which normally lie below the Dungy Drift, but are here uppermost, as all the seams lie reversed. The Dungy Drift Seam lies at an angle of 45°, dipping southwards, while the New Rock Series has only a dip of 35° in the same direction.

From the spoil-heap at Newbury Colliery I obtained a dark-blue shale containing *Lingula mytiloides*. In determining the horizon whence this shale came, Mr. J. W. Cottle rendered considerable assistance. Fortunately for purposes of localization, but one coal, that known as the No. 1 Seam, has been worked for some time, and therefore it is almost a certainty that the *Lingula*-Shale found at the pit-surface came from the roof of this seam.

An incline passes down to the seam from the Luckington shaft, and some evidence of this Linguliferous horizon ought to be obtained on the spoil-heap of the latter colliery. Mr. Cottle added that, if these fossils had come from Mackintosh Colliery, which lies to the west of Newbury Colliery, they would have been derived from the black shales normally overlying the Coking Coal or Dungy Drift, but now forming its floor on account of the overturning of the seams.

From Mackintosh Colliery I obtained, not a *Lingula* Shale, but a dark compact shale which yielded ostracods and a fragmentary valve of *Anthracomya*. One small *Estheria*-like fossil has a length of 4 millimetres and a depth of 3 mm., and is flatly convex. It seems a more rounded form than *E. tenella*, but is somewhat suggestive of that species.

The Radstock Area.

An examination of the spoil-heaps of collieries in the Radstock area yielded evidences of faunal horizons at several collieries. At the Radstock collieries it is impossible to trace the shales back to their source of origin, because the spoil-heap is the common dumping-ground from several pits. The material obtained from this common spoil-heap is dealt with in the accompanying palæontological notes under the head of 'mixed material.' The spoil-heap in question is that at Tyning Batch, and material from the colliery at Wellsway is conveyed underground to Ludlows Colliery, and thence discharged upon Tyning Batch, which also receives the material from Ludlows, Middle Pit, and Tyning. This uncertainty

as to the particular colliery from which material came is regrettable, because the fossils found are well-marked species and well preserved; they include forms referable to *Anthracomya williamsoni*, *A. lanceolata*, *A. minima*, and *A. phillipsi*.

(7) Ludlows and Middle Pits.

These collieries, originally sunk to the Radstock Series, have since been deepened to the Lower or Farrington Series, and now pass through the following seams:—

First, or Radstock Series.	Great Seam.
	Top Little.
	Middle.
	Slyving.
	Under Little.
	Bull Seam.
Second, or Farrington Series.	No. 1 or Rock Vein.
	No. 2 Vein.
	No. 3 Vein.
	No. 4 Vein.
	No. 5 or Smith's Coal.
	No. 6 or Bottom Vein.
	No. 7 Vein, proved, but not yet worked.

A large quantity of shale described by the miners as coming from the 'deep,' in all probability came from Nos. 1, 5, & 6 Veins of the Second or Farrington Series. The shale yielded *Anthracomya lanceolata* and *A. minima*.

It is quite within the bounds of possibility that the fossils found in the 'mixed' shales of Tyning Batch came from one or more of these horizons, although we must not lose sight of the fact that they might have come partly from Tyning or Wells Way Pits, where the Radstock Series has been or is now being worked.

(8) Foxcote and Lower Writhlington Collieries.

These collieries are opened up in the Second or Farrington Series of coals. The highest workable seam is that known as the 'Rock' or 'Badger' Vein, which has been worked at Braysdown Colliery, Foxcote, Lower Writhlington, and Middle and Ludlows Pits at Radstock. It is worked at the Greyfield Colliery, Clutton, at the present time, and also at the first five of the above mentioned collieries. The 'Badger' or 'Rock' Vein occurs at a depth of 1131 feet in the Lower Writhlington pit, and at 1059 feet in that of Foxcote. About 300 feet lower down occurs another seam, known as the 'Smith' Seam. From the roof of the Rock or Badger Vein at Radstock, I was enabled, by the kindness of Mr. G. E. J. McMurtrie, to obtain a quantity of shale which on examination yielded examples of *Anthracomya phillipsi* and *A. lanceolata*. The specimens of *A. phillipsi* were few in number, while *A. lanceolata* proved fairly abundant.

The shale is of a dark greyish-blue colour, breaks irregularly, and contains the shells in an uncrushed condition.

The spoil-heap of the Foxcote and Lower Writhlington Collieries also yielded *Anthracomya lanceolata*, *A. phillipsi*, *A. lævis*, *A. minima*, *Naiadites elongata*, and *Pseudoedmondia* sp. nov.

(9) Dunkerton.

The Dunkerton Old and New Pits pass through the First or Radstock Series of coals, which, as we have seen, also occur in the Ludlows and Middle Pits. In hard micaceous shale from Dunkerton New Pit I obtained the posterior half of a single fish-scale of *Cœlacanthus* cf. *elegans*.

Regarding the Upper Division of Radstock as a whole, it may be said that the Farrington or Lower Series promises to be especially productive, if it can be worked in regular order and thoroughly; but this is a costly and difficult process. Access to the beds can only be obtained in the mines, and in galleries which usually are heavily timbered and constantly traversed by loaded wagons.

List of Fossils found.

Estheria tenella Jordan.
Estheria sp.
Bairdia cf. *ampla?* (Reuss).
Bairdia (?)
Leaia leidyi Lea, var. *salteriana* Jones.

Carbonicola cf. *acuta* (Sowerby).
Carbonicola cf. *aquilina* (Sowerby).
Carbonicola sp.
Anthracomya williamsoni (Brown).
Anthracomya phillipsi (Williamson).
Anthracomya minima (Ludwig).
Anthracomya lanceolata Hind.
Anthracomya sp.
Naiadites elongata Hind.
Naiadites carinata (Sowerby).
Naiadites sp.
Pseudoedmondia sp. nov.
Pterinopecten papyraceus (Sowerby).
Nucula oblonga (M'Coy).

Lingula mytiloides Sowerby.

Loxonema sp.
Indet. gen. & sp. (?)

Gastrioceras listeri (Martin).
Gastrioceras diadema ? (Beyrich).
Glyphioceras sp.

Insect-wings.

Strepsodus sauroides (Binney).
Megalichthys pygmæus Traquair.
Cœlacanthus elegans Newberry.
Coprolites.

Palæoxyris helicteroides (Morris).

Palæontological Notes.

OSTRACODA and PHYLLOPODA.

Estheria tenella Jordan. (Pl. XXVII, figs. 1 & 2.)

This species occurs in the shale bearing *Leaia leidyi*, var. *salteriana* at Coalpit Heath, but in less abundance than that fossil. Isolated and well-preserved examples are rare, the specimens usually forming dense clusters, which must have numbered some hundreds of individuals. The valves in these clusters are crushed and ill-defined, but in most cases a broadly oval outline can be distinguished, as also faint traces of concentric striations. Isolated examples are better

preserved, and show the essential characters of the species. The best example is that of the left valve with a well-marked and perfectly straight hinge-line. The umbo is small and crushed, and does not overlap the hinge-line. The anterior valve-margin is almost truly semicircular, the ventral margin being broadly rounded, and passing directly into the more broadly rounded posterior margin which curves upwards and forwards to the hinge-line. Traces of numerous fine concentric lines of growth are present on the margin of the valve, the inner portion being almost smooth, and marked with what appears to be a faint reticulation. The free margin of the valve is somewhat inflected along its whole length.

Horizon and locality.—Roof-shales over the High Vein, Coalpit Heath. *Estheria* cf. *tenella (?)* occurs at 'Horizon 3' between the Ashton and Bedminster Great Veins, South Liberty Colliery, Bristol. (See Pl. XXVII, fig. 3.)

ESTHERIA sp.

A few examples of a smaller species of *Estheria* occur in the same shale as the last, but are specifically indeterminable.

Horizon and locality.—Roof-shales over the High Vein, Coalpit Heath; and at 276 feet below the Bedminster Great Vein, South Liberty Colliery, Bristol.

BAIRDIA cf. AMPLA? (Reuss). (Pl. XXVII, fig. 4.)

Certain elongate oval shells are referred to the genus *Bairdia*. They are 6 millimetres long and 3 mm. broad. Each valve is flatly convex, broadest in the middle part of the length, and closely applied along the margin to the opposite valve. No trace of a hinge-line or of lines of growth can be distinguished. The surface of each valve is crossed by three vertical, bluntly-rounded ridges which do not reach the dorsal or ventral margins. In two specimens where one valve has been crushed into the interior of the other, the vertical ridges stand out in higher relief.

Horizon and locality.—276 feet below the Bedminster Great Vein, South Liberty Colliery, Bristol.

LEAIA LEIDYI Lea, var. SALTERIANA Jones. (Pl. XXVII, figs. 5 & 6.)

During Mr. D. G. Lillie's investigations of the fossil flora of the Bristol Coalfield,[1] he found upon the spoil-heap at Coalpit-Heath Colliery a small quantity of black shale containing fossils new to him: these he kindly placed at my disposal. A subsequent visit to the colliery resulted in the finding of many more, and it became clearly evident that a well-defined faunal horizon existed in the Coal-Measures at this colliery. Examination of the shale showed that it contained abundant fine examples of the usually rare phyllopod, *Leaia leidyi* var. *salteriana*, associated

---

[1] 'Notes on the Fossil Flora of the Bristol Coalfield' Geol. Mag. dec. 5, vol. vii (1910) p. 58.

with *Estheria* cf. *tenella (?)*, *Bairdia* cf. *ampla (?)*, *Estheria* sp , *Anthracomya williamsoni*, and the following plant-remains :—

Cordaites angulosostriatus Grand'Eury.
Cordaites-leaves.
Lepidophyllum sp.
Lepidodendron sp. (*rimosum* Sternberg ?)
Annularia cf. *stellata* (Schloth.).
Caulopteris sp.
Pecopteris sp.
Pecopteris cf. *miltoni* (Artis).
Sphenopteris neuropteris Boulay.

The agent of the Colliery Company, Mr. Hewitt, and the manager, Mr. Eames, readily assisted in identifying the shale lying upon the spoil-heap, which they considered came from the roof of the High Vein. At my request, a quantity of fresh material was cut out from the roof of this seam and brought to the surface, when the horizon was at once put beyond doubt, the fresh material containing hundreds of specimens of *Leaia* at all stages of growth. Frequently this fossil occurred in clusters of a score or more, the clusters being distributed sporadically over the slabs of shale. The smallest forms are not more than 2 millimetres long, and all sizes between this and 8 mm. in length are met with. They are not always parallel to the bedding-plane of the shale, but disposed at various angles. The stout straight ribs which stand in high relief upon the surfaces of the valves vary in number with the size of the fossil, small forms having as few as twelve lateral ridges and adult forms nineteen.

A cross-section of the valves shows that the dorsal face of each rib is hollowed, the free edges of the ridges forming sharp knife-like edges inclining towards the umbo. The lower or ventral surface of each edge is convex. The radial ridges are sharply angulated, prominent, and crossed by the concentric ribs, which in well-preserved valves may impart to the line of the ridges a somewhat crenulated appearance. The hinge-line posterior to the umbo is slightly excavated in some examples, enclosing a narrow elongated area, which appears to have remained always open in the form of a lunule. In front of the umbo, the hinge-line is carried a little forward, and then merges into a well-rounded anterior border. All the specimens found agree in general and detailed characters with *Leaia leidyi*, var. *salteriana*, being shorter, deeper, and more rounded than in the type-species of the genus or of the variety *williamsoni*.

The best-preserved forms show a well-marked convexity of the valves and a fairly prominent incurved umbo. Paired valves are rarely met with. Where they do occur, they show a markedly truncated hinder border, which is very characteristic. The regular curvature of the anterior and ventral borders is one of the chief distinctions of the variety.

Horizon and locality.—Roof-shales of the High Vein, Parkfield Series, Coalpit-Heath Colliery.

PELECYPODA.

Carbonicola acuta (Sowerby).

Posterior halves of two shells, showing the lines of growth and the hinder end of the hinge-line. Both specimens are crushed flat, and somewhat distorted.

Horizon and locality.—138 feet below the Bedminster Great Vein, South Liberty Colliery, Bristol.

Carbonicola aquilina (Sowerby).

One specimen only of this species was found in shale upon the pit-heap at Easton Colliery. The few other fossils found at this colliery came from the roof-shales of the Kingswood Great Vein, and there is reason to believe that this specimen is from the same horizon.

Horizon and locality.—Roof-shales of the Kingswood Great Vein, Easton Colliery, Bristol.

Carbonicola sp.

A small crushed shell, not more than 3 millimetres long, too indeterminate for accurate description. In its produced anterior border, which bends around the relatively broad umbo and curves in towards the hinge-line, the specimen, notwithstanding its extremely small size, is decidedly of a *Carbonicola* type.

Horizon and locality.—621 feet below the Bedminster Great Vein, South Liberty Colliery, Bristol.

The absence of *Carbonicola*, except as one of the rarest of fossils, is a remarkable feature in the Bristol Coalfield. Had it occurred here, as in other coalfields, in such profusion as to form 'mussel-bands,' the fact must have been noted long ago in sinkings. The place of *Carbonicola* seems to be taken in some degree by *Anthracomya*.

Anthracomya williamsoni (Brown).

Examples of this species are rare. The shell is very thin, and often absent, leaving a smooth-surfaced internal cast. When present, the shell is marked by very fine lines of growth, most evident on the antero-ventral margin. The shale in which the specimens are found appears similar to that yielding *A. phillipsi*, but the two species have not been seen in association.

Horizon and locality.—Second Series of the Upper Coal-Measures, Writhlington Colliery, Radstock.

Anthracomya phillipsi (Williamson).

Several fine examples of this species were obtained from a compact black shale, which was recognized by miners as occurring near the Toad Vein at South Liberty Colliery. The outline of the shell in several instances is perfect, and the wrinkled periostracum is

well marked, although the shell itself is as thin as tissue-paper. Examples of this species were also found in a heavy black bituminous shale with plant-remains, forming 'Horizon 4,' at about 138 feet below the Bedminster Great Vein at the same colliery. In the roof-shales of the High Vein, in the Parkfield Series of the Upper Coal-Measures at Coalpit-Heath Colliery, the remains of this species are rarely in anything like good condition, although portions of shell are met with frequently, the part most often preserved being the posterior ventral margin. In the two best specimens found, the length along the antero-posterior diagonal is 20 mm. The small anterior end is not easily distinguished, but the straight hinge-line and shell-margin are perfectly clear. No evidence of tumidity is present—the valves lying flat upon the shale, and showing the somewhat irregular and unequal lines of growth. The periostracum is usually present and much wrinkled.

Dr. Wheelton Hind records this species from the Lower Coal-Measures of the Speedwell Pit, Kingswood (Gloucestershire).[1] The discovery was made by the late Mr. Stock, but the horizons were not determined. At Writhlington Colliery in the Radstock district, Mr. D. M. Watson, of Manchester University, found several fine examples on the spoil-heap, and others have since been collected by me. Most of the forms at this colliery have the valvular ridge much more oblique and pronounced than in specimens figured by Dr. Wheelton Hind in his monograph, while elongated examples are not uncommon. In the latter forms, the hinge-line is long and the posterior ventral border expanded. The umbo in the Writhlington specimens is tumid, and in well-preserved examples slightly overhangs the hinge-line. The shells occur in a soft black shale with ironstone bands, which splits up very irregularly. The horizon is not known.

At Foxcote Colliery, the examples of this species are found in shales of the Second Series of the Upper Coal-Measures, and are unusually well preserved for so fragile a form. The wrinkles of the periostracum follow in the main the concentric lines of growth; but this is not always the case, examples being found in which the wrinkles are at right angles to the lines of growth, or form an irregular meshwork. Uncrushed shells are fairly numerous, and even in those which are crushed the umbones still retain something of their tumidity. The rock is a dark shale, breaking irregularly, and containing irregular masses of dark-brown material much similar to coprolitic matter. A few ostracods are scattered through the shale.

Anthracomya phillipsi was also obtained from the roof-shales of the Easton Great Vein at Easton Colliery. It presents no features of special interest, occurring sparingly in a compact black shale, which is well-bedded. The Easton Great Vein of the Lower Coal-Measures has been correlated with the Kingswood Great Vein.

---

[1] '*Carbonicola, Anthracomya, & Naiadites*' Pal. Soc. Monograph (1894–96) p. 121.

Three examples of *A. phillipsi* were obtained from a large Upper Coal-Measure pit-heap at Tyning Batch. In all of them, the shell was excessively thin, with a much wrinkled periostracum. As previously mentioned, the spoil-heap at Tyning Batch receives all the débris from four collieries, namely, Wellsway, Middle, Ludlows, and Tyning collieries: all working in the Upper Coal-Measures, but not all in the same series. The difficulty of localizing the fossiliferous shale is, therefore, insuperable.

Some examples of this ubiquitous species were obtained from the roof-shales of the Rock or Badger Vein, of the Second or Farrington Series of Radstock. The occurrence of this seam in numerous collieries in the Radstock district has been elsewhere mentioned.

A few of the examples of *A. phillipsi* that have been found are of comparatively large size, somewhat gibbous at the umbo, and possess a much wrinkled periostracum.

From the foregoing remarks it will be evident that *Anthracomya phillipsi* is equally abundant in the Lower Coal-Measures of the Bristol district and in the Upper Series of Radstock.

Horizons and localities. — Lower Coal-Measures: Vicinity of the Toad Vein and 138 feet below the Bedminster Great Vein, South Liberty Colliery; roof-shales of the Easton Great Vein, Easton Colliery; and Speedwell Colliery, Kingswood.

Upper Coal-Measures: Roof of the High Vein, Coalpit-Heath Colliery; Writhlington Colliery, Radstock; Foxcote Colliery, Radstock; and the waste-heap of Tyning Batch.

ANTHRACOMYA LANCEOLATA Hind. (Pl. XXVII, figs. 7-9.)

This species was founded by Dr. Wheelton Hind[1] upon a single specimen obtained at Glebe Colliery, Fenton (Staffordshire), where a number of seams in the Middle Coal-Measures are worked. Although Dr. Hind failed to find any other example of this species in the collections that he examined, there is no doubt that it is by no means a rare fossil in the Bristol Coalfield. A single left valve 27 millimetres long was found in massive black shale at Ludlow Colliery, Radstock, associated with *A. minima*. Other examples occur in Lower Coal-Measure shales from the Speedwell Colliery, Kingswood; and four almost whole and uncrushed examples were found upon the large spoil-heap of Upper Coal-Measure shales at Tyning Batch. The latter specimens lie in a fine black shale which splits very irregularly, and shows no evident lamination or bedding-planes. Finally, from the roof-shales of the Rock or Badger Vein in the Second or Farrington Series of Radstock, I obtained quite a numerous suite of specimens—several in very good condition and uncrushed. One of these was submitted to Dr. Wheelton Hind, who confirmed my determination of the species. The numerous examples collected have been subjected to a critical

---

[1] '*Carbonicola, Anthracomya, & Naiadites*' Pal. Soc. Monogr. (1894–96) p. 104 & pl. xv, figs. 11–11 *a*.

examination; and I am of opinion that the form ought to be regarded as a variety of *Anthracomya williamsoni*, and not as a true species.

Horizons and localities. — Lower Coal-Measures; Speedwell Colliery, Kingswood, Bristol; roof-shales over the Rock or Badger Vein in the Second or Farrington Series, Radstock district.

Upper Coal-Measures: Spoil-heap of Tyning Batch, Radstock.

ANTHRACOMYA MINIMA (Ludwig). (Pl. XXVII, figs. 10–13.)

This species occurs at Radstock; at Speedwell Colliery, Kingswood; and at three of the four faunal horizons lying between the Ashton seams and the Bedminster Great Vein, at South Liberty Colliery. The shells vary in length from 4 to 8 millimetres, and in one instance the valves were found united. Specimens found in the Second Series of the Upper Coal-Measures at Writhlington Colliery, Radstock, are extremely well preserved in an earthy ironstone, and show admirably the short hinge-line, the gentle curvature of the valves, and the broad ovate outline of the shell. Wrinkling of the periostracum is present, but of a finer character than in *A. phillipsi*, and it never masks the concentric lines of growth. Upon the Upper Coal-Measure spoil-heap at Tyning Batch several good examples were found in a dark shale, very similar in appearance and character to a dark Upper Coal-Measure shale found at Foxcote Colliery. The largest specimen obtained had an antero-posterior length of 13 millimetres and a depth of 7. Good examples of the species were obtained from a massive black shale in the Upper Coal-Measures at Ludlows Colliery, where they occurred in association with *A. lanceolata*. Two of the attached valves show the whole length of the hinge-line and the umbones in close apposition: a lunule also appears to be present. Quite a numerous series was obtained from dark, compact, Upper Coal-Measure shales at Foxcote Colliery, and all the specimens were in excellent condition.

Adult individuals of the species form in outline a fairly regular oval, disposed somewhat obliquely to the hinge-line. The regularity of this oval is but slightly broken dorsally, by the hinder border of the hinge-line. The latter is straight, extending over half the length of the shell in very young forms, while in older examples it may occupy but a third of the length. The umbones are small, gently rounded, moderately tumid, and lie opposite the junction of the anterior and middle thirds of the hinge-line.

The posterior ventral border is short, well rounded, and forms the lowest part of the shell. From the posterior ventral border the posterior margin passes forwards and upwards, sometimes almost straight, sometimes with a slight sulcus, until it meets the hinder end of the hinge-line in a definite and very obtuse angle. In young forms, the umbones seem almost median to the hinge-line in position. The surface of the valves is marked by a great number of concentric lines of growth, much more closely packed than in *Anthracomya phillipsi*. They are also clearly independent of

the thin, much wrinkled periostracum which overlies them, the wrinkling of the latter diverging in every direction.

Young individuals are much less oblique than older forms, and have a somewhat rounded quadrangular outline.

A number of beautifully preserved specimens were obtained from the Upper Series of the Upper Coal-Measures of Radstock. They serve to show that the roughly quadrangular form which this species possesses when young is also retained in adult age if the specimen be well preserved, and further that the shell is strongly tumid. A few examples were found in well-bedded Lower Coal-Measure black shale at Speedwell Colliery. There is no little difficulty in separating this form from *Anthracomya lævis* var. *scotica*: the latter is, on the whole, not so robust a species, and is more broadly ovate.

Horizons and localities.—At Horizons 1, 2, and 3 below the Bedminster Great Vein, Lower Coal-Measures, South Liberty Colliery, Bristol; in black shale, Lower Coal-Measures, Speedwell Colliery, Kingswood; in the roof-shales of the Rock or Badger Vein, Second Series of the Upper Coal-Measures at Writhlington Colliery, Radstock; spoil-heap at Tyning Batch, Radstock; in the Second Series of the Upper Coal-Measures at Foxcote Colliery, Radstock.

NAIADITES ELONGATA Hind. (Pl. XXVII, fig. 14.)

A series of uncrushed and well-developed examples of this species were found at Horizon 2, in the Lower Coal-Measures at South Liberty Colliery. The resemblance, as they lay in the shale, to *Anthracomya minima* was extremely close; but subsequent liberation of one entire specimen showed conclusively that it belonged to *Naiadites*. Dr. Wheelton Hind[1] has already noted this close superficial resemblance. The shell is markedly tumid in both valves, transversely elongated, and would be somewhat modioliform were it not for the well-developed posterior angle of the hinge-line. Only the faintest trace of lines of growth can be distinguished. Several of the specimens occur in a compact brown ironstone. From the roof-shale of the High Vein at Coalpit Heath was obtained the greater part of a right valve. It occurred in black shale charged with plant-remains, and in association with *Leaia leidyi* var. *salteriana*. As the valve is uncrushed, the *Anthracomya*-like appearance is well shown, and indeed there is nothing externally evident which would remove this species from that genus. A finely-preserved left valve from Radstock has come into our possession. Like all the rest, it is markedly tumid.

Horizons and localities.—Horizon 2 below the Bedminster Great Vein, Lower Coal-Measures, South Liberty Colliery, Bristol; roof-shales of the High Vein at Coalpit-Heath Colliery, Coalpit Heath; shales over the Rock or Badger Vein in the Second Series of the Upper Coal-Measures, Writhlington Colliery, Radstock.

---

[1] '*Carbonicola, Anthracomya, & Naiadites*' Pal. Soc. Monogr. (1894–96) p. 143.

NAIADITES cf. CARINATA (Sowerby). (Pl. XXVII, fig. 15.)

The cast of a pair of attached valves and two larger crushed valves were found in a dark shale at Easton Colliery. I consider them to be examples of this species. The attached valves, though small, and in the condition of internal casts, are in very good preservation, the anterior adductor muscle-scar impression standing up in relief upon the left valve. The umbones are small, in apposition, and angulated. An oblique ridge passes backwards from the umbo to the posterior ventral border, broadening out towards the latter. In front of the oblique ridges, the cast shows a shallow fold deepening anteriorly and ending under the umbones, imparting to the latter a pinched appearance when viewed from the front. The crushed valves are 10 millimetres long.

Horizon and locality.—Black Shale, Easton Colliery.

NAIADITES sp.

The impression of a *Naiadites* somewhat resembling *N. elongata* occurs in well-bedded Lower Coal-Measure black shale, in association with *Anthracomya williamsoni*, from the Speedwell Colliery, Kingswood, Bristol.

PSEUDOEDMONDIA (?) sp. nov. (Pl. XXVII, fig. 16.)

Considerable interest attaches to this specimen, owing to the rarity of occurrence of luciniform mollusca in the Carboniferous formations. Only one specimen was found, in a dark-grey Upper Coal-Measure shale at Writhlington Colliery, Radstock. It consists of two attached valves having a length of 8 millimetres, and a depth of 6 mm. in the right valve, which is almost fully exposed. The umbones are small, incurved, a little anterior to the centre of the hinge and directed forwards. They are moderately tumid, and encroach upon, but do not hide, the hinge-line. A small elongated lunule lies in front of the umbones. The hinge-line is straight, a little less than the greatest length of the shell, and passes into the anterior and posterior borders at an obtuse angle. The anterior border curves forwards and downwards from the hinge-line, and passes in a well-rounded curve into the ventral border, which is but slightly convex in outline. The posterior border is regularly rounded. The general appearance of the valve is that of a broad oval. The valves are somewhat tumid, the elevation of the umbones spreading out equally in all directions to the middle of the shell, from which it gradually dies out in the margin. The ligament is thin, slightly elevated and rounded, and passes forward, disappearing between the umbones. The surface of the shell is smooth, but shows under magnification a series of concentric lines of growth, well spaced out over the middle of the valve, and crowded together along the anterior and posterior borders.

Horizon and locality.—In massive dark-grey shale, Upper Coal-Measures, Writhlington Colliery, Radstock.

PTERINOPECTEN PAPYRACEUS (Sowerby).

A very small fragment of the shell of this species was found in massive dark shale at Horizon 3, below the Bedminster Great Vein. The close radiating ribs of this species are so typical, that even minute fragments can be recognized.

Horizon and locality.—In dark shale, about 279 feet below the Bedminster Great Vein, Lower Coal-Measures, South Liberty Colliery, Bristol.

NUCULA OBLONGA M'Coy. (Pl. XXVII, fig. 17.)

Two good examples of this species were obtained at Horizon 3. The shells measure 7 millimetres in antero-posterior diameter and 4 in depth.

Dr. Wheelton Hind[1] describes this species as very rare, and as only known to occur in the Upper Limestone Shales of Scotland, and in arenaceous shale at Drumlish (Ireland).

Horizon and locality.—In dark shale, 279 feet below the Bedminster Great Vein, Lower Coal-Measures, South Liberty Colliery, Bristol.

BRACHIOPODA.

LINGULA MYTILOIDES Sowerby.

In Lower Coal-Measures at the Easton and Hanham Collieries occurs a fine black shale crowded with hundreds of the shells of *Lingula*. Most of the shells are small, but admirably preserved. On the spoil-heap at Hanham Colliery, where the greater number were obtained, much of the shale has been fired; but even in burnt material the shells are distinctly shown. They vary in length from 2 to 6 millimetres, are broadly oval, and have moderately swollen and often highly polished umbones. At Newbury the species is found in a dark-blue Lower Coal-Measure shale: the shells are more uniform than at Easton or Hanham, the length of the valves varying between 3 and 5 mm., and in all cases the periostracum is much wrinkled. The shales at Easton and Hanham Collieries are typical '*Lingula* Shales,' and very similar to those found at much lower horizons in the Ashton-Vale Colliery, Bristol.

Horizons and localities.—In the neighbourhood of the 'Five Coals' Seam, Easton Colliery, Bristol; ? Roof of No. 1 Seam, Newbury Colliery, Coleford, near Radstock.

GASTEROPODA.

A few gasteropods were found in Lower Coal-Measure shales thrown out upon the spoil-heap at South Liberty Colliery; but, with one exception, all were minute and too destitute of determinable characters to be described.

---

[1] 'Monogr. Brit. Carb. Lamellibr.' Pal. Soc. vol. i (1896–1900) p. 188.

LOXONEMA sp.

The single exception above-mentioned is an acutely turreted shell 5 to 7 millimetres in height, and consisting of six whorls. In general character it agrees with *Loxonema ashtonense*, obtained by me from an adjacent colliery and described in this Journal.[1] The surface of the shell is smooth, and lacks the longitudinal striæ seen in *L. ashtonense*. I regard it as a species allied to the latter, but the specimen is not sufficiently good to serve as the type of a new species.

Horizon and locality.—Shales in the neighbourhood of the Toad Vein, Lower Coal-Measures, South Liberty Colliery, Bristol.

CEPHALOPODA.

A small collection of goniatites was obtained, along with the gasteropods, upon the spoil-heap of South Liberty Colliery. A small series of minute coiled shells found in the shales may possibly be the fry of goniatites, or of gasteropods, or of both.

GASTRIOCERAS LISTERI (Martin).

A portion of the outer whorl of a large shell of this species was found.

Horizon and locality.—Shales in the neighbourhood of the Toad Vein, Lower Coal-Measures, South Liberty Colliery, Bristol.

GLYPHIOCERAS DIADEMA ? (Beyrich).

A very small pyritized fragment of the inner whorls of a goniatite fortunately showed traces of the suture-lines, and I am indebted to my friend Mr. G. C. Crick for his views of its relationship.

Horizon and locality.—Shales in the neighbourhood of the Toad Vein, Lower Coal-Measures, South Liberty Colliery, Bristol.

Evidence of the occurrence of large goniatites has been obtained in ironstone nodules, found upon the spoil-heap in Lower Coal-Measures at Hanham Colliery. The material is very refractory, and in no case could a specimen be got out, or uncovered in such a way as to secure a clue to its genus and species.

INSECTA.

GENENTOMUM SUBACUTUM, sp. nov. (Pl. XXVII, figs. 18 & 19.)

Two small wing-fragments, 9 millimetres in length and 6 mm. in breadth. One wing is partly superposed upon the other, the lower one having its surface also in part concealed by matrix. The uppermost wing is represented by a fragment of the distal hinder portion, and by the wing-apex, which is bluntly rounded. The whole aspect of the wing-fragment is pyriform; but this is doubtless misleading, as the outer margin is broken away, and no true approximation to the original size or shape can be obtained. The

---

[1] 'On a Marine Fauna in the Basement-Beds of the Bristol Coalfield' vol. lxiii (1907) p. 464 & pl. xxx, figs. 17 *a*–17 *c*.

surface is crossed by one vein forking three times, and by five other veins, two of which bifurcate twice. All the veins are narrow and deep, while the interspaces are crossed at right angles by transverse veins which divide them into somewhat regular rectangular areas. Where forking of the veins takes place, the resultant branches first diverge rapidly, and then pass outwards at right angles to the wing-margin in parallel lines. The upper and lower branches of the third and fourth veins appear to run together, and must ultimately fork a little beyond the present broken edge. The hinder edge is somewhat sinuated. There can be no doubt, however, that the margin is broken away, and still hidden under the matrix of the counterpart block of shale.

Notwithstanding the fragmentary character of the wing, it is, I believe, possible to determine that the veins described are portions of the radius, the trifurcate upper vein forming the apex of the radius, and extending somewhat forward of the tip of the wing. A little of the distal outer margin can be traced in front of the tip of the wing. The small area enclosed between it and what I suppose to be the main axis of the radius (that is, the trifurcate vein) is crossed by fine, short, deeply-incised veins. The lower wing-fragment has a well-defined outer (?) margin evidently bounded by the costal vein. It is regularly and broadly convex, and shows signs of passing into a straight or incurved line proximally. The tip of the wing is narrow and bluntly rounded. Five longitudinal veins are present, the third forking just in front of the fractured proximal edge. The fifth vein forks about 2·5 millimetres below the tip of the wing. All the veins run out into the costal margin.

These wings, fragmentary though they be, present features of unusual interest, as they are wholly unlike blattoid wings in every particular; and their relationship must be sought for in other groups. The resemblance in venation and in structure to fragments of locustid wings is remarkably close. There are the small, thin, sharp longitudinal veins in each; the division of the interspaces by transverse branches into rectangular areas; and the fragments show a texture which was quite filmy, apart from the marks left by the veins: this again is a locustid feature.

Wings of this character were classed by Scudder in a genus *Genentomum*, referred by him to the family Homothelidæ. Brauer found an affinity in Scudder's form to the Sialids, while Brongniart recognized its relationship to the Orthopteres *sensu stricto*.[1] Dr. Handlirsch refers Scudder's genus to a new family Œdischiidæ, in which the forms are characterized by the coalescence of the superior branch of the median vein of the front wing with the radial sector, and its bifurcation farther out as an apparent offshoot of the latter vein.

So far as determination of such fragments is possible, I should assign the above-described specimens to Scudder's genus *Genentomum*

---

[1] A. Handlirsch, 'Revision of American Palæozoic Insects' Proc. U.S. Nat. Mus. vol. xxix (1906) pp. 661–820, especially pp. 700–701.

with its distinct locustid affinities. It is interesting to note that Dr. Handlirsch has observed that in one of the forms of this group the hind legs were developed for jumping, precisely as in locustids.

Horizon and locality. — 637 feet below the Bedminster Great Vein and 137 feet above the Ashton Great Vein, Lower Coal-Measures, South Liberty Colliery, Bristol.

PISCES.

Cœlacanthus cf. elegans Newberry.

Horizon and locality.—Micaceous shale of the Upper Series, Upper Coal-Measures, Dunkerton Colliery.

Strepsodus sauroides (Binney).

Impression of a scale, in dark-blue shale seamed by brown earthy ironstone-bands.

Horizon and locality.—Dark-blue shale near the Rock or Badger Vein, Second Series of the Upper Coal-Measures, Writhlington Colliery, Radstock.

Megalichthys pygmæus Traquair.

Fragment of dentary in Lower Coal-Measure *Lingula* Shale. Hanham Colliery.

Coprolites.

Several small coprolites occur in the *Anthracomya-phillipsi* Shale at Easton Colliery.

INCERTÆ SEDIS.

Palæoxyris helicteroides (Morris). (Pl. XXVII, figs. 20 & 21.)

One example of this still problematic form was found at a depth of 279 feet below the Bedminster Great Vein. It presents the usual fusiform body, and is broken off a little above the point at which it is joined by the pedicle. The beak is almost intact, but the segments, instead of running parallel and longitudinally to the apex as described by Dr. Moysey,[1] continue the spiral twists seen upon the body. The specimen is either more attenuated than usual, or partly concealed along the sides. The total length is 25 millimetres and the maximum breadth 4 mm., the beak being about 12 mm. long. The alternation of broad and narrow bands characteristic of *P. helicteroides* is clearly marked, and is continued upon the beak, where the bands lose most but not all of their spiral character.

The whole question of *Palæoxyris* and its affinities has been so recently considered by Dr. Moysey *(op. cit.)* that nothing need be added here, beyond the record of its presence in the Lower Coal-Measures of the Bristol Coalfield

---

[1] 'On *Palæoxyris* & other allied Fossils from the Derbyshire & Nottinghamshire Coalfield' Q. J. G. S. vol. lxvi (1910) p. 331.

SYNOPSIS OF THE FAUNA OF THE BRISTOL COAL-MEASURES.	LOWER COAL-MEASURES.			UPPER COAL-MEASURES.		
	Vobster, Ashton & Bedminster Series.	New Rock Series.	Pennant Grit.	Second or Farrington Series.	Red Ground.	First or Upper Radstock Series.
Echinodermata.						
Crinoidal columnals	×	...	...	...	...	...
Vermes.						
Worm-burrows	×	...	...	...	...	...
Spirorbis pusillus (Martin)	×	...	...	...	...	...
Brachiopoda.						
Lingula mytiloides Sowerby	×	...	...	×	...	×
Orbiculoidea nitida (Phillips)	×	...	...	...	...	...
Orthotetes cf. *crenistria* (Phillips)	×	...	...	...	...	...
? *Derbya senilis* (Phillips)	×	...	...	...	...	...
Chonetes cf. *hardrensis* Phillips	×	...	...	...	...	...
Chonetes sp.	×	...	...	...	...	...
Productus cf. *antiquatus* Sowerby	×	...	...	...	...	...
Productus concinnus Sowerby	×	...	...	...	...	...
Ambocœlia aff. *urii* (Fleming)	×	...	...	...	...	...
Pelecypoda.						
Carbonicola cf. *acuta* (Sowerby)	×	...	...	...	...	...
Carbonicola cf. *aquilina* (Sowerby)	×	...	...	...	...	...
Carbonicola sp.	×	...	...	...	...	...
Nucula æqualis Sowerby	×	...	...	...	...	...
Nucula oblonga M'Coy	×	...	...	...	...	...
Nuculana acuta (Sowerby)	×	...	...	...	...	...
Parallelodon tenuistriatus (M'Coy)	×	...	...	...	...	...
Tellinomorpha (?) hindii Bolton	×	...	...	...	...	...
Posidoniella kirkmani (Brown)	×	...	...	...	...	...
Posidoniella lævis (Brown)	×	...	...	...	...	...
Posidoniella minor (Brown)	×	...	...	...	...	...
Schizodus antiquus Hind	×	...	...	...	...	...
Aviculopecten gentilis Sowerby	×	...	...	...	...	...
Pterinopecten carbonarius Hind	×	...	...	...	...	...
Pterinopecten papyraceus (Sowerby)	×	...	...	...	...	...
Palæolima retifera Hind (MS.)	×	...	...	...	...	...
Pseudoedmondia, sp. nov.?	...	...	...	...	...	×
Modiola, sp. nov.?	×	...	...	...	...	...
Anthracomya lanceolata Hind	×	...	...	×	...	...
Anthracomya minima (Ludwig)	×	...	...	×	...	...
Anthracomya phillipsi (Williamson)	×	...	...	×	...	...
Anthracomya williamsoni (Brown)	×	...	...	×	...	...
Naiadites elongata Hind	×	...	...	×	...	...
Naiadites cf. *carinata* (Sowerby)	×	...	...	...	...	...
Naiadites sp.	×	...	...	...	...	...

SYNOPSIS OF THE FAUNA OF THE BRISTOL COAL-MEASURES (*continued*).	LOWER COAL-MEASURES.			UPPER COAL-MEASURES.		
	Vobster, Ashton & Bedminster Series.	New Rock Series.	Pennant Grit.	Second or Farrington Series.	Red Ground.	First or Upper Radstock Series.
Gasteropoda.						
Raphistoma acutum Bolton	×	...	...	...	...	...
Raphistoma radians (de Kon.)	×	...	...	...	...	...
Pleurotomaria carinata (Sowerby)	×	...	...	...	...	...
Pleurotomaria gemmulifera (Phillips)	×	...	...	...	...	...
Euphemus urii (Fleming)	×	...	...	...	...	...
Bellerophon bicarenus Lév.	×	...	...	...	...	...
Bellerophon hiulcus Martin	×	...	...	...	...	...
Flemingia sp.	×	...	...	...	...	...
Macrocheilus cf. *ventricosus* de Kon.	×	...	...	...	...	...
Loxonema ashtonense Bolton	×	...	...	...	...	...
Loxonema scalaroideum Phillips	×	...	...	...	...	...
Loxonema sp.	×	...	...	...	...	...
Naticopsis disjuncta Bolton	×	...	...	...	...	...
Cephalopoda.						
Orthoceras cf. *conquestum* (de Kon.)	×	...	...	...	...	...
Orthoceras cf. *cylindraceum* Fleming	×	...	...	...	...	...
Pleuronautilus costatus Hind	×	...	...	...	...	...
Nautiloid shell	×	...	...	...	...	...
Temnocheilus cf. *tuberculatus* Sowerby	×	...	...	...	...	...
Glyphioceras coronatum Foord & Crick	×	...	...	...	...	...
Glyphioceras diadema ? (Beyrich)	×	...	...	...	...	...
Gastrioceras listeri (Martin)	×	...	...	...	...	...
Arthropoda.						
Leaia leidyi var. *salteriana* Jones	...	...	×	...	...	...
Estheria tenella Jordan	...	...	×	...	...	...
Estheria sp.	...	...	×	...	...	...
Bairdia cf .*ampla* (Reuss)	...	...	×	...	...	...
Bairdia sp.	×	...	...	...	...	...
Genentomum subacutum sp. nov.	×	...	...	...	...	...
Pisces.						
Diplodus gibbosus (Binney)	×	...	...	...	...	...
Pleuroplax rankinei (Hanc. & Att.)	×	...	...	...	...	...
Megalichthys pygmæus Traquair	...	...	...	...	...	...
Strepsodus sauroides (Binney)	...	...	...	×	...	...
Cœlacanthus elegans Newberry	×	...	...	...	...	×
Rhadinichthys monensis (Egerton)	...	...	...	...	...	...
Elonichthys sp.	×	...	...	...	...	...
Acrolepis sp.	×	...	...	...	...	...
Coprolites	×	...	...	...	...	...
Palæoxyris helicteroides (Morris)	×	...	...	...	...	...

Range of Species.

The accompanying synopsis (pp. 337–38) comprises the fossil forms from the Bristol Coalfield that have been determined by the writer during recent years. It shows that the Ashton and Bedminster Series of Bristol, the Coalpit-Heath and Parkfield Series of the northern part of the Coalfield, and the Vobster Series of Radstock which form the basement series of the Lower Coal-Measures, are all characterized by a fauna agreeing with the typical fauna of the Lower Coal-Measures in the coalfields of the Midlands and of Lancashire and Yorkshire.

There is, however, a dearth of species of *Carbonicola*, while the fauna is poor in cephalopods and fishes. Gasteropods are, however, almost as abundant in species as in other coalfields.

No forms are known from the New Rock Series of the Lower Coal-Measures; but this is probably due rather to lack of opportunity for examining adequately the measures, than to an actual paucity of fossils. The Second or Farrington Series of the Upper Coal-Measures has yielded one brachiopod *(Lingula mytiloides)*, several species of ostracods, four species of *Anthracomya*, and one fish *(Strepsodus sauroides)*. All the species of *Anthracomya* found in the Farrington Series, as well as *Strepsodus sauroides*, also occur in the Lower Coal-Measures.

Cœlacanthus elegans occurs in the First or Upper Radstock Series. Both *Strepsodus sauroides* and *Cœlacanthus elegans* are typical Lower Coal-Measure forms, which in the Bristol Coalfield pass up much higher in the Coal-Measures than they do elsewhere.

The tabulation of species establishes, moreover, the fact that marine horizons are not restricted to the Lower Measures, but also occur in the Upper Coal-Measures.

Similar evidence of the upward range of marine phases in the Coal-Measures has been recently obtained in the Yorkshire Coalfield at Maltby, where Mr. W. H. Dyson[1] found an extensive fauna in four horizons, the lowest being 340 feet above the Barnsley Coal, and the highest occurring 1000 feet below the summit of the Middle Coal-Measures. This marine fauna is essentially of the type formerly regarded as restricted to the Lower Coal-Measures, if we except the well-known marine band in the Middle Coal-Measures found by the late Prof. A. H. Green at Dukinfield. It also shows some relation to the marine fauna of the Bristol Coalfield. This is demonstrated by the presence of *Loxonema ashtonense* in a marine band lying about 709 feet above the Barnsley Coal. This fossil was first described by me from the Ashton-Vale Colliery, Bristol, where it occurs low down in the Lower Coal-Measures. Other forms common to the Bristol and Yorkshire higher measures are *Lingula mytiloides* and *Cœlacanthus*. The discoveries in the Yorkshire Coalfield emphasize the fact, much

---

[1] 'The Occurrence of Marine Bands at Maltby' Geol. Mag. dec. 5, vol. vii (1910) p. 520.

more than the forms now recorded from the Bristol Coalfield, that marine phases are not restricted to the Lower Series, but pass upwards to near the top of the Middle Coal-Measures in Yorkshire and into the Farrington Series of the Upper Coal-Measures in the Bristol and Somerset area.

Further, it is evident that the marine fauna undergoes no marked change throughout—forms common in the Lower Coal-Measures ranging upwards, and not being replaced by new species. This lack of mutability will probably prevent the use of marine bands for zonal purposes. The continuity of life-forms in the Middle Coal-Measures of Yorkshire is strikingly complete, less so in the Bristol Measures; but even here the long interval represented by the deposition of over 1000 feet of Pennant Grit has not sufficed to prevent their recurrence at higher levels.

The presence of fragments of insect-wings in the Lower Coal-Measures at South Liberty Colliery, Bristol, is of interest and suggestive, since insect-wings are also known in the South Wales Coalfield,[1] which must originally have been joined up to the Bristol Coalfield.

It may not be inopportune to put on record my conviction that the three Coal-Measure genera, *Carbonicola*, *Naiadites*, and *Anthracomya*, will yet prove to be characterized by only a few definitely marked forms worthy of specific rank, and that around each of such species it will be possible to group a number of variants, some of which are now regarded as valid species. It is quite possible to select two or more types, and between such selected forms to place a graduated series which effectually bridges the interval, so that one selected species seems to pass by a series of stages into another. This is easily done with several of the present species of *Carbonicola*, which can be thus joined up with *C. aquilina* and *C. acuta*.

The power of variation or mutability (in De Vries's sense) possessed by these genera would seem to have been very great, or their response to the conditions of environment very ready. I am also inclined to the belief that dissimilar and relatively fixed species occurring at widely separated horizons have produced under the stimulus of environment, or of some other cause, a series of variants or mutations precisely similar in outward form and character.

EXPLANATION OF PLATE XXVII.

Fig. 1. *Estheria tenella* Jordan. Magnified 3 diameters. Roof-shales over the High Vein, Coalpit-Heath Colliery. (See p. 324.)

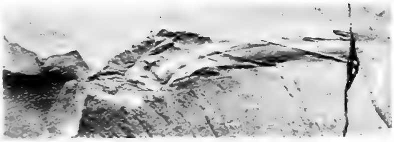
2. *Estheria tenella* Jordan. Portion of a clustered mass showing the general mode of occurrence. Natural size. Same horizon and locality as fig. 1.

3. *Estheria* cf. *tenella* Jordan. In shale between the Ashton and Bedminster Great Veins, South Liberty Colliery, Bristol. A smaller and more oval form than the Coalpit-Heath type, magnified 3 diameters. (See p. 325.)

---

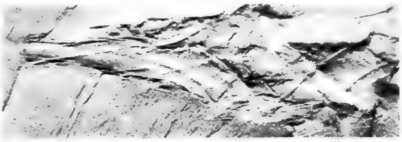
[1] Q. J. G. S. vol. lxvii (1911) pp. 149–74 & pls. vii–x.

20



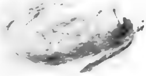
X 2

21



X 2

9

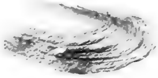


X 1

8

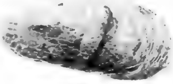
X 1

7



X 1. 5

14



X 1

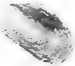
16

X 2

17

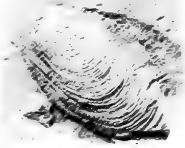
X 3

15



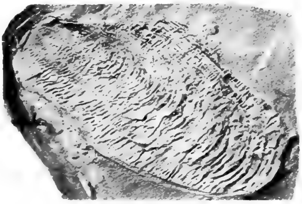
X 1

10



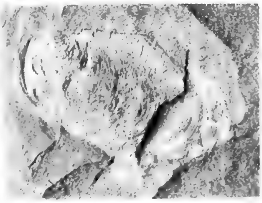
X 2

11



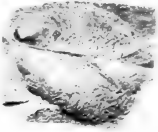
X 2

12



X 3

13



X 2

4

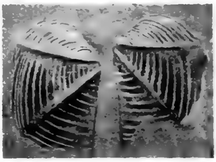
X 3

18

19

X 2. 5

5

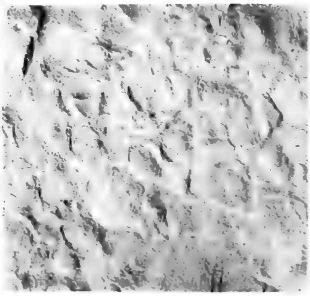


X 3

3

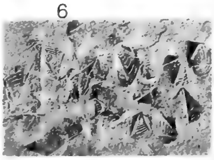
X 3

2



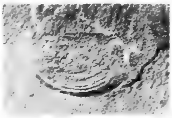
X 1

6



X 1

1



X 3

J. W. Tutcher, Photo.

Bemrose Ltd., Collo., Derby.

MARINE FOSSILS FROM THE BRISTOL COAL-MEASURES.

Fig. 4. *Bairdia* cf. *ampla* (Reuss). Magnified 3 diameters. In shale 276 feet below the Bedminster Great Vein, South Liberty Colliery, Bristol. (See p. 325.)

5. *Leaia leidyi*, var. *salteriana* Jones. Roof-shales over the High Vein, Parkfield Series, Coalpit-Heath Colliery. Paired valves. Magnified 3 diameters. (See p. 325.)

6. *Leaia leidyi*, var. *salteriana* Jones. Portion of a clustered mass, showing the general mode of occurrence. Natural size.

7. *Anthracomya lanceolata* Hind. Uncrushed valve from the roof of the Badger Vein, Second or Farrington Series, Radstock. Magnified 1·5 diameters. (See p. 329.)

8. *Anthracomya lanceolata* Hind. Conjoined valves. Natural size. Radstock.

9. *Anthracomya lanceolata* Hind. Right valve somewhat flattened. Natural size. Ludlows Colliery, Radstock.

10. *Anthracomya minima* (Ludwig). Young shell with short hinge-line. Magnified 2 diameters. Upper Coal-Measures, Foxcote Colliery, Radstock. (See p. 330.)

11. *Anthracomya minima* (Ludwig). Adult shell showing increased development of hinge-line, marked obliquity of valve, and much wrinkled periostracum crossed by lines of growth. Magnified 2 diameters. Upper Coal-Measures. Foxcote Colliery, Radstock.

12. *Anthracomya minima* (Ludwig). Short, somewhat quadrangular form with small well-developed umbo. Magnified 3 diameters. Foxcote Colliery, Radstock.

13. *Anthracomya minima* (Ludwig). Attached valves showing the straight hinge-line, and small pointed umbones which are almost in apposition. Magnified 2 diameters. Ludlows Colliery, Radstock.

14. *Naiadites elongata* (Hind). Natural size. Shales over Rock or Badger Vein, Second Series of the Upper Coal-Measures, Writhlington Colliery. (See p. 331.)

15. *Naiadites* cf. *carinata* (Sow.). Natural size. Black shale, Easton Colliery. (See p. 332.)

16. *Pseudoedmondia (?)* sp. nov. Attached valves. Magnified 2 diameters. Upper Coal-Measures, Writhlington Colliery, Radstock. (See p. 332.)

17. *Nucula oblonga* (M'Coy). Magnified 3 diameters. In shale, 279 feet below the Bedminster Great Vein, Lower Coal-Measures, South Liberty Colliery, Bristol. (See p. 333.)

Figs. 18 & 19. *Genentonum subacutum*, sp. nov. Magnified 2·5 diameters. In shale, 637 feet below the Bedminster Great Vein, Lower Coal-Measures, South Liberty Colliery, Bristol. (See p. 334.)

20 & 21. *Palæoxyris helicteroides* (Morris). Magnified 2 diameters. Showing the spiral arrangement of the segments continued upon the beak. (See p. 336.) In shale, 279 feet below the Bedminster Great Vein, Lower Coal-Measures, South Liberty Colliery, Bristol.

13. FAUNAL *and* LITHOLOGICAL SEQUENCE *in the* CARBONIFEROUS LIMESTONE SERIES (AVONIAN) *of* BURRINGTON COMBE (SOMERSET).

By Prof. SIDNEY HUGH REYNOLDS, M.A., F.G.S., and ARTHUR VAUGHAN, M.A., D.Sc., F.G.S. (Read May 10th, 1911.)

[PLATES XXVIII–XXXI.]

CONTENTS.

I. INTRODUCTION.

THE magnificent section of Burrington Combe, first studied by Prof. C. Lloyd Morgan,[1] was described in considerable detail in 1905 by Mr. (now Dr.) T. F. Sibly.[2] This author laid down, as accurately as was possible at the time of his publication, the broad zonal sequence of the faunas. The very large amount of research that, during the last six years, has been devoted to the Carboniferous Limestone Series, both in the British Isles and in Belgium, has demonstrated the importance of more detailed lithological investigations and the possibility of tracing the evolution and migration of the great Carboniferous gentes of Corals and Brachiopods.

The field-work has extended over several years, and we owe much to the willing assistance of many Bristol geologists, especially to Mr. W. H. Wickes and Mr. H. F. Barke.

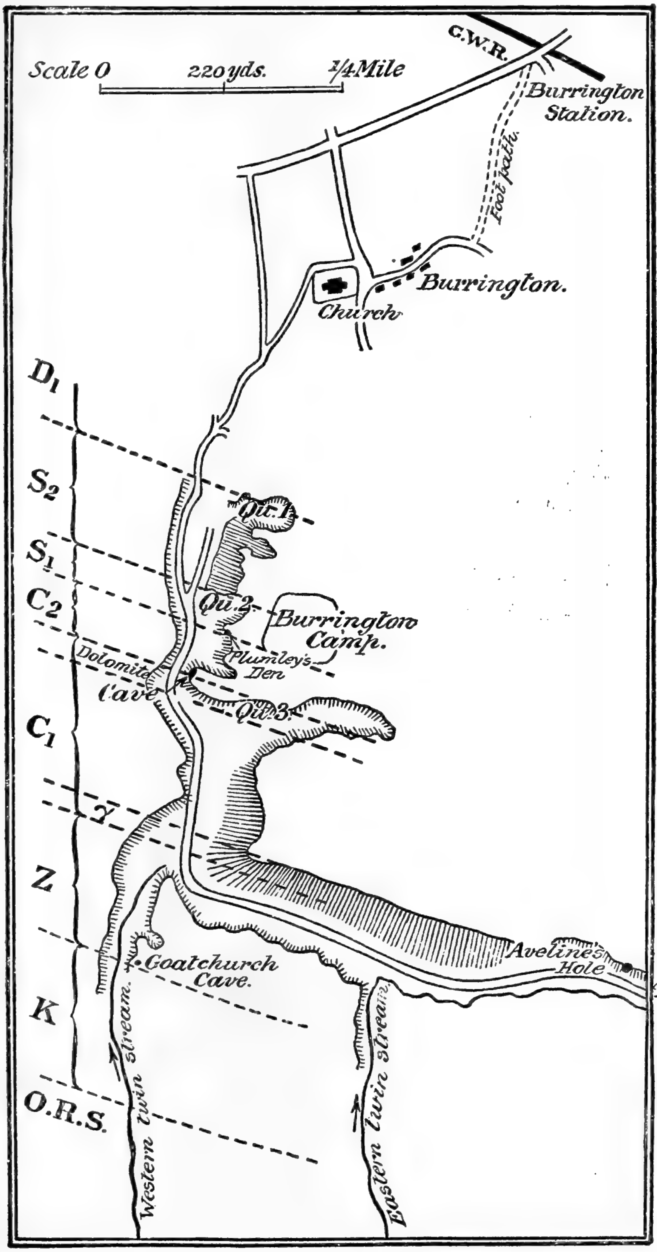
The series of views (figs. 3–10, pp. 354–61) illustrate the whole sequence, and are labelled with zonal and faunal indices; the precise points at which important rock-types occur are also marked upon them by means of numerals.

---

[1] 'Mendip Notes' Proc. Bristol Nat. Soc. n. s. vol. vi (1889–91) p. 169.

[2] 'The Carboniferous Limestone of Burrington Combe' Proc. Bristol Nat. Soc. ser. 4, vol. i (1904–1907) p. 14; see also A. Vaughan, 'Palæontological Sequence in the Carboniferous Limestone of the Bristol Area' Q. J. G. S. vol. lxi (1905) pp. 248–50.

Fig. 1.—*Map of Burrington Combe and the immediate neighbourhood.*



II. DESCRIPTION OF THE IMPORTANT ROCK-TYPES, ARRANGED ZONALLY AND LITHOLOGICALLY. (S. H. R.)

[The traverse is from north to south, the zones being thus encountered in descending order.]

VISÉAN.

LOWER *DIBUNOPHYLLUM* ZONE (D_1).

Extent.—The top of Quarry 1 and the hillside on the north.

Thickness.—A thickness of about 20 feet is exposed in the quarry, and perhaps 80 feet beyond it.

The D beds exposed consist entirely of fine-grained and crystalline grey limestone. The red coloration, which is as a rule so characteristic of the D beds of the Bristol district, is not seen at Burrington. The rocks exposed in the quarry are uniformly and somewhat strongly crinoidal. In some bands *Dibunophyllum* is sufficiently abundant to form an appreciable part of the rock. Sections show that the limestone exposed on the hillside is full of foraminifera, and much like that forming the bulk of the S and C_2 beds.

UPPER *SEMINULA* ZONE (S_2).

Extent.—From nearly the top of Quarry 1 to nearly the top of Quarry 2.

Thickness.—540 feet.

The S_2 beds may be subdivided as follows, in descending order:—

S_2 (*d*). Thinly-bedded, very variable series, consisting in the main of compact horny limestone (china-stone) often concretionary and showing imperfect 'Cotham-Marble' structure, alternating with limestone often oolitic containing *Seminula* bands, and including a more shaly development in the upper part. This horizon is the representative of the 'concretionary beds' of the Avon, Sodbury, and other sections in the neighbourhood of Bristol, and is exposed in Quarry 1.

S_2 (*c*). Fine-grained, generally foraminiferal grey limestone, with *Seminula* bands. Exposed on the hillside.

S_2 (*b*). Fine-grained grey limestone, containing many strong bands of *Lithostrotion martini* and much chert. Exposed on the hillside.

S_2 (*a*). Grey limestone, commonly oolitic; the upper beds are very poorly exposed on the hillside, the lower are well seen in Quarry 2. A little dolomitization has occurred at one level in the upper beds.

Further Account of the Lithology of the S_2 Beds.

Many of the lithological types occurring in the Burrington section are identical with those of the Avon section, and have been already

described by one of us.[1] The 'china-stones' of the Burrington section agree with those of the Avon section in their extremely compact horny texture and conchoidal fracture, but are not so black on a freshly-broken surface, and do not weather so white as do those from S_1 in the Avon section.

The 'concretionary beds,' which are best seen at about the middle of the quarry, are essentially the same as those of the Avon section, and the account given in the paper already referred to of the peculiar 'Landscape' or 'Cotham-Marble' structure is applicable to the Burrington rocks. Sections (see Pl. XXVIII, fig. 1) show that this type of rock is to a large extent made up of a mass of small interlacing tubules, which Dr. Bather suggests may be calcareous algæ. Dr. G. J. Hinde has kindly examined two slides containing these bodies, and writes as follows:—

> 'They have the appearance, as you say, of intertwining tubules, but I do not detect any definite walls to the tubes, if they are such. Still, it is quite possible that they might be tubules or canals in which the walls have disappeared. They remind me strongly of the structure of the peculiar bodies from the Carboniferous Limestone of Belgium, described by Prof. Gürich, of Breslau, under the name of *Spongiostroma*.[2] Gürich places his forms as protozoans, but cannot indicate any particular group of Protozoa as nearly related. Prof. Rothpletz describes somewhat similar bodies from the Silurian of Gotland and from Œsel, and he considers them as hydrozoa.'[3]

At several points the limestone of S_2 shows brecciation. In Quarry 1 a distinct type occurs, consisting of fragments of horny or more or less oolitic limestone which reach a length of an inch and a half, and are united by rather coarsely crystalline calcite. At other levels the brecciation is on too small a scale to be visible in a hand-specimen. In the oolitic limestone from the upper part of S_2 the grains tend to be relatively large and somewhat scattered: the centre round which a grain has formed is frequently a foraminifer (see Pl. XXVIII, fig. 2). Sometimes the concretionary coating of calcium carbonate is developed round a *Seminula* in the way described by one of us, in the case of the 'brecciated pisolite' of the Avon section.

S_2 (*c*). These rocks occupy the northern third of the hillside between Quarries 1 and 2. Their base is taken as being marked by the highest chert-band. They are in the main foraminiferal limestones with bands of *Seminula*, but are sometimes oolitic and include, especially in the upper part, very fine-grained, compact, horny limestone (41)[4] of china-stone type, but differing from the more

---

[1] Proc. Bristol Nat. Soc. ser. 4, vol. i (1906-1907) pp. 87-100.

[2] See 'Les Spongiostromides du Viséen de la Province de Namur' Mém. Mus. Roy. Hist. Nat. Belg. vol. iii (1906) pp. 1-55 & pls. i-xxiii; also Neues Jahrb. vol. i (1907) pp. 131-38 & pl. ix.

[3] See K. Svenska Vetensk.-Akad. Handl. n s. vol. xliii (1908) No. 5, pp. 17-20 & pls. v-vi.

[4] The numerals in parentheses refer to particular spots shown in figs. 3-10 (pp. 354-61) at which important rock-types were obtained.

typical china-stone of the overlying strata in containing numerous foraminifera.

S_2 (*b*). This division includes the limestone with chert-bands occupying the middle third of the hillside between Quarries 1 and 2.

These limestones are, as a rule, characterized by their highly foraminiferal and often oolitic nature, but they include in the upper part some bands of very fine-grained horny limestone of china-stone type. At (20)—see Pl. XXVIII, fig. 3—occurs an interesting rock-type. It consists largely of very irregular, commonly well-rounded fragments of compact horny limestone, frequently enclosing a foraminifer or a bit of a crinoidal ossicle, the whole being united by a cement of crystalline calcite. In this case, after the penecontemporaneous brecciation of the limestone, the fragments were rounded, either by rolling or by solution, before being united in the crystalline matrix. All these various processes were probably quite rapidly carried out.

The most marked feature of the rocks of this horizon is, however, afforded by the cherts, of which there are some six bands frequently associated with bands of *Lithostrotion*. In colour these cherts are generally pale pinkish-grey. A section cut from one at (17) was kindly examined by Dr. G. J. Hinde, who confirmed the attribution of certain rod-like fragments to sponge-spicules, suggesting that they were parts of the anchoring spicules of hexactinellid sponges. With regard to certain round bodies which it was suggested were radiolaria, Dr. Hinde writes as follows:—

> 'The round bodies are small siliceous spheres with a smooth exterior and a relatively thick wall, enclosing a central area which is now infilled with silica of a different tint from that of the wall. The wall is traversed by numerous radiating straight spines or spokes, which connect the inner area with the outer surface of the sphere. These seem to me to be really minute pores or canals now infilled with silica of the same tint as that of the central area of the sphere. The spheres are from 0·1 mm. to 0·13 mm. in diameter, and their walls from 0·025 mm. to 0·04 mm. in thickness. Assuming that these bodies were originally siliceous, which seems to have been the case, I should judge that they are radiolaria.'

Bands full of papilionaceous *Chonetes* also occur.

S_2 (*a*). This band includes (1) the ill-exposed limestone between the top of Quarry 2 and the lowest chert-bands, and (2) the limestone exposed in Quarry 2 as far as the prominent rib of rock which is taken as marking the base of S_2. The upper ill-exposed beds consist in the main of grey foraminiferal and not markedly oolitic limestone, but near the edge of the quarry an oolitic character begins to be apparent.

At (89) a brown bed occurs which is in the main a finely oolitic limestone, the grains being often formed round foraminifers. Between the grains is crystalline calcite; and numerous, minute, brown patches of associated dolomite and chalybite crystals are seen in thin sections to be the cause of the coloration.

A peculiar fault-breccia, consisting of pieces of limestone set in a very ferruginous matrix, occurs immediately below this slightly dolomitic band, but is very poorly exposed. It is a noteworthy point that there are signs of disturbance accompanied by the occurrence of unusual minerals—in this case fluor, at the corresponding horizon in the Great Quarry of the Avon section.

The basal beds of S_2 seen in the quarry are strongly oolitic and often finely banded limestone, which alternates with fine-grained grey limestone not obviously oolitic in hand-specimens, but commonly shown by thin sections to be so. Crinoids are also an important constituent of these limestones. Penecontemporaneously brecciated limestone (3) occurs, similar to that described above at (20) and below at (111). (See Pl. XXVIII, fig. 4.)

LOWER *SEMINULA* ZONE (S_1).

Extent.—From the prominent rib of rock near the middle of Quarry 2, past the end of the quarry as far as Plumley's Den. Also the prominent rock-mass on the western side of the Combe, as far as the cleft known as the 'Rock of Ages,' which is due to weathering along the same band as is Plumley's Den.

Thickness.—130 feet.

The prominent rib of rock which it is convenient to take as marking the boundary between S_1 and S_2 consists of thinly-bedded and partly dolomitized limestone-bands alternating with thin shaly partings. The dolomite in this case was probably due to local infiltration. The main part of S_1 consists, however, of rather thickly-bedded, fine-grained, grey limestone, as a rule obviously oolitic, and probably oolitic even when this character is not visible in a hand-specimen. Fine banding is frequent.

Further Account of the Lithology of the S_1 Beds.

Though the great majority of the limestones in S_1 agree in being strongly oolitic and foraminiferal, they show a considerable amount of variability. Some (6) are almost entirely composed of small and uniform oolitic grains; others (111) are very similar in character to the variety described above at (20), consisting of rounded patches of limestone, sometimes horny, sometimes oolitic, which have clearly been produced by the brecciation of pre-existing beds—succeeded in the first place by a more or less complete rounding of the edges of the resulting fragments, and in the second place by the deposition in certain cases of successive coats round the fragments in concretionary fashion, followed finally by the union of the whole in a cement of crystalline calcite (see Pl. XXVIII, fig. 4).

Other rocks again from this level are partly oolitic, partly of the brecciated type of limestone just described. A considerable amount of petroleum occurs in the limestone at the level of Plumley's Den and of the cleft in the 'Rock of Ages.' This feature may be observed at the same level in the Avon section.

Upper *Syringothyris* Zone (C_2).

Extent.—From Plumley's Den past 'The Cave' to the top of Quarry 3.

Thickness.—320 feet.

In the Avon section this horizon shows a very marked division into an upper series of shales and dolomites, the '*Caninia* Dolomites,' and a lower thick band of white oolite, the '*Caninia* or Gully Oolite.' In the Burrington section the great thickness of limestone forming C_2 shows no such division, but is throughout very uniform, being almost always oolitic or foraminiferal, or exhibiting the two characters combined. The upper 150 feet or so, as one passes southwards from Plumley's Den, is in the main a very conspicuous white oolite, and an oolitic character is strongly in evidence at the base in the higher beds of Quarry 3; but between these points the limestone is rather foraminiferal (see Pl. XXVIII, fig. 5) than oolitic, and even in the oolitic limestone foraminifera are very abundant and frequently form the centres for the larger grains. Between 'The Cave' and Quarry 3, finely broken-up crinoid stems form an important component of the limestone.

The peculiar type of brecciated limestone with penecontemporaneously rounded fragments, already mentioned as occurring in S_2 and S_1 (see Pl. XXVIII, figs. 3 & 4), is met with again at various points (9, 118, 56) in the upper part of C_2.

TOURNAISIAN.

Lower *Syringothyris* Zone (C_1, including γ).

Extent.—From the top of Quarry 3, along the ill-exposed part of the hillside to about two-thirds of the way down the Great Scarp.

Thickness.—740 feet.

The general succession of the rocks of this level is as follows, in descending order:—

C_1 (*b*). Dolomitized limestone. 240 feet.
C_1 (*a*). Fine-grained, grey, generally crinoidal limestone. 350 feet.
γ 150 feet. { Highly fossiliferous, commonly crinoidal limestone, with much chert.
Fine-grained, grey, crinoidal limestone, often highly fossiliferous. This is identical with the 'Petit Granit' of the Belgian geologists.

Further Account of the Lithology of the C_1 Beds.

Although the dolomitization which has taken place at this level is not so marked as it is in the Avon section, it is still by far the most important feature of the upper part of C_1 (see Pl. XXVIII, fig. 6 & Pl. XXIX, fig. 1). The dolomitized rocks[1] clearly were originally crinoidal and foraminiferal limestones containing a large proportion of a calcareous paste or matrix, and it is interesting

---

[1] Our observations are in close accord with those of Mr. E. E. L. Dixon, Summary of Progress for 1905' Mem. Geol. Surv. 1906, p. 48.

to compare the relative resistance of these several constituents to the process of dolomitization. The first material to be affected is the fine calcareous matrix, then the foraminifera are attacked; while the pieces of crinoid stem formed of crystalline calcite are highly resistant, and may remain unaffected when the whole of the surrounding material is dolomitized.

As regards the conditions of formation of these dolomites, the facts appear to be in conformity with the now generally accepted view—that they originated by the practically contemporaneous alteration of limestone under shallow-water conditions. It is a well-established fact that shallowing of the water of the Carboniferous Limestone sea took place throughout the main part of the South-Western Province in Middle Avonian times; and the occurrence of these dolomites on the same general horizon as the shallow-water beds elsewhere, is evidence that the shallowing extended to the Mendip area. Below the dolomites is a highly fossiliferous series forming the remainder of C_1 and γ. The limestones of this level are entirely non-oolitic, and are in the main fine-grained and dark grey. Corals, brachiopods, and especially crinoids abound, and sections show polyzoa and foraminifera to be frequent.

The name ‘Petit Granit’ is employed by Belgian geologists to designate a rock mainly made up of larger crinoid-fragments embedded in a matrix of smaller ones. It occurs commonly in the γ beds and in the upper part of Z_2 (see Pl. XXIX, fig. 2).

Upon the cherts, which are very prominent, the formation of the splendid scarp of the upper part of the Combe partly depends.

Upper *Zaphrentis* Zone (Z_2).

Extent.—The lower slopes of the Great Scarp and the projecting mass of rock at the bend of the Combe.

Thickness.—140 feet.

Lithologically the Z_2 beds closely resemble the γ beds: differing in the absence of chert-bands; in the occurrence of shaly partings; and in their thinly-bedded character, so that they weather easily. They consist of dark-grey, generally crinoidal and highly fossiliferous limestone, much being of the ‘Petit Granit’ type.

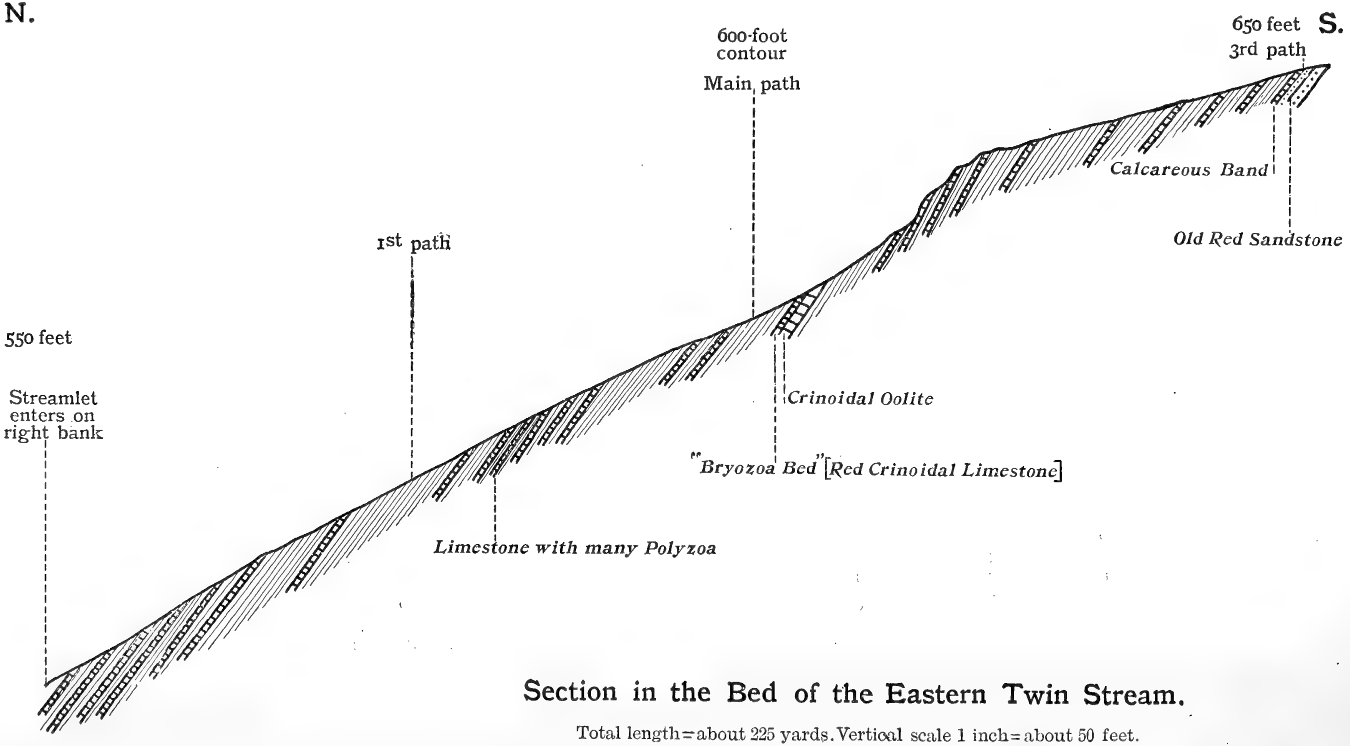
Lower *Zaphrentis* Zone (Z_1).

Extent.—The main part of the exposures in the valley of the western twin-stream, from the Goatchurch cave to the road; and the corresponding series in the eastern twin-stream. Almost all the southern face of the upper part of the Combe, except just at the bend, is formed by Z_1 beds.

Thickness.—140 feet.

A type of limestone similar to that in Z_2 prevails also in Z_1.

Fig. 2.



Section in the Bed of the Eastern Twin Stream.

Total length = about 225 yards. Vertical scale 1 inch = about 50 feet.

CLEISTOPORA ZONE (K).

Extent.—The whole series between the Old Red Sandstone and the commencement of the massive limestone of the *Zaphrentis* Beds. The beds are exposed in the twin-streams which enter the Combe from the south. In the western stream the K beds commence at about the position of the Goatchurch cave. While the K_1 and lower K_2 beds are fairly exposed, especially in the eastern stream, the upper K_2 beds can scarcely be seen at all.

Thickness.—500 feet.

The K beds show a greater amount of lithological variation than any other part of the section, and are the only part of it in which grit-bands occur, or in which true shales have any appreciable development.

UPPER *CLEISTOPORA* ZONE (K_2).

Extent.—From about the level of the Goatchurch cave in the western twin-stream, or its equivalent position in the eastern, to above the point where the main hillside path crosses the eastern twin-stream.

In the western twin-stream the highest exposure of the K_2 beds is a fine-grained crinoidal limestone (122) just below the Goatchurch cave; there is a similar exposure at a little waterfall about 30 yards higher up, after which the exposures become very bad. In the eastern twin-stream there are no exposures of the highest beds; but, at a point where a minute feeder of the stream (shown in the 6-inch Ordnance map) enters on the east, a fairly continuous section commences and extends to the base of K_2. The rocks consist entirely of narrow bands of dark crinoidal limestone containing many brachiopods, alternating with shales which do not as a rule split well and have often a tendency to conchoidal fracture. In the lower part of the series are several bands of crinoidal limestone crowded with polyzoa and small gastropods (see Pl. XXIX, fig. 3), and comparable to bands occurring at the same horizon in the Avon section and at Portishead. This polyzoa-band is also seen in the western stream.

LOWER *CLEISTOPORA* ZONE (K_1, including Km).

Extent.—In both twin-streams the K_1 beds may roughly be said to occupy the stream-course between the upper and the main paths, commencing at about the level of the main path and passing down into the Old Red Sandstone at about the level of the upper path.

The lithological variability stated to be characteristic of the K beds is especially marked in the case of the K_1 beds. In the eastern

twin-stream, where the best section occurs, the succession is as follows (see also fig. 2, p. 350):—

7. Shales.
6. Crinoidal limestone with polyzoa, similar to bands in K_2.
5. Coarsely crystalline limestone with mud-pans.
4. 'Bryozoa Bed' (140)—red, highly crystalline and crinoidal limestone: about 3 feet.
3. Coarsely oolitic and crinoidal limestone (139): about 5 feet.
2. Thick shale, in places crowded with ostracods.
1. Shales alternating with limestone-bands, including one full of small *Chonetes*. A grit-band occurs near the base, and below it is a calcareous band (142) containing crinoids, while immediately below that is the Old Red Sandstone.

Further Account of the Lithology of the K_1 Beds.

In these are several bands of considerable lithological interest. Band 4, the equivalent of the 'Bryozoa Bed' of the Avon and other sections, is a ferruginous, highly crinoidal limestone (see Pl. XXIX, fig. 4). Sections show a considerable number of polyzoa, much iron-stained, and occupying spaces between the crinoidal ossicles. This horizon has not been detected in the western twin-stream.

Band 3 is the coarsest and most remarkable oolite occurring in the whole section, and is precisely comparable to a band occurring at the same level in the Skrinkle section near Tenby. The oolitic grains, which generally are extremely regular, are in the majority of cases developed round a fragment of a crinoid-stem (see Pl. XXIX, fig. 5). The rock contains a large proportion of iron-oxide. This horizon has not been detected in the western twin-stream.

Band 2.—The well-bedded, somewhat gritty shales are commonly crowded with ostracods, and are well exposed in the eastern twin-stream. In the western stream ostracods are equally plentiful in (126) a calcareous grit (see Pl. XXIX, fig. 6), occurring at rather a lower level.

Summary of the Lithology.

(A) Calcareous Rocks.

Horny limestone, nearly structureless in thin sections, and concretionary limestone, showing imperfect 'Cotham-Marble' structure, are practically confined to the upper part of S_2, although horny limestone occurs to a slight extent in S_1.

Oolitic structure.—A band of coarse oolite occurs in the upper part of K_1; but, apart from this, no oolite is met with until the top of C_1 is reached. C_2 and S_1 are very largely oolitic; there is much oolite at the base of S_2; and coarse oolite occurs in the upper part of S_2. Most of the oolitic grains show no centre, some are developed round quartz-grains, many round foraminifera in the C and S beds, while the very coarse oolite in the K beds has most

of the grains developed round bits of crinoid-stems. The peculiar pisolite-breccia is confined to the S beds.

Foraminiferal limestone.—Foraminifera are the principal limestone-builders throughout C_2, S_1, and much of S_2. A large proportion of the oolitic limestones are strongly foraminiferal; but, especially in C_2, there is much limestone abounding with foraminifera and yet not oolitic. H. B. Brady, in the Introduction to his Monograph on the Carboniferous and Permian Foraminifera (Pal. Soc. 1876), after referring to various deposits, such as the White Chalk and the Nummulitic Limestone, as being formed almost exclusively of the remains of foraminifera, says that in Britain no portion of the vast series of beds known as Mountain Limestone has any claim to be placed in the same category, except the *Saccammina* Limestone (p. 4). This statement does not hold good with regard to the rocks at Burrington, some parts of C_2 being probably as foraminiferal as the Chalk. As regards the genera of foraminifera present, *Endothyra*, *Valvulina*, and *Trochammina* appear to be the commonest, and have been found at numerous levels from the base of C_2 to the top of S_2. *Textularia* is the next commonest, and *Nodosaria* has been noted at several levels.

Coral-limestone.—Coral-bands are prominent at the following levels:—

(*a*) In D_1: where certain bands contain *Dibunophyllum* and *Cyathophyllum* in abundance.

(*b*) In S_2 and at the base of S_1: where *Lithostrotion martini* occurs in large masses, and is the main component of thick beds of limestone.

(*c*) In C_1 below the dolomitized beds: here *Caninia cylindrica* is very abundant.

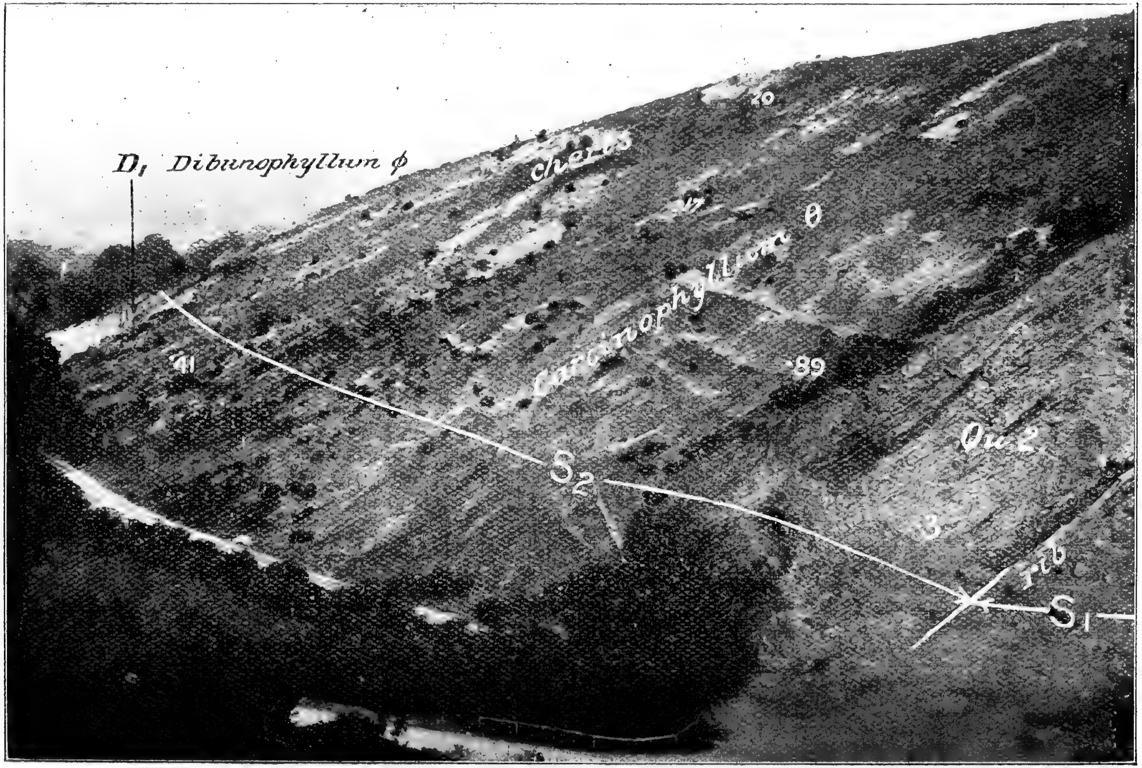
Brachiopod limestone.—Throughout the *Seminula* Zones bands crowded with *Seminula* are frequent; and, in places, as near the top of S_2, bands composed of giganteid *Producti* occur. There is a marked band of papilionaceous *Chonetes* at the base of the dolomites of C_1. Bands full of *Spirifer clathratus* and *Chonetes hardrensis* are a feature of Z_1 and Z_2. Brachiopods almost vie in importance with crinoids as limestone-builders in K.

Crinoidal limestone.—Crinoids are the prevalent limestone-builders throughout K, Z, and C_1. They also play an important part at the base of D_1 and C_2.

Polyzoa are sufficiently plentiful at certain levels in K_2 to form an appreciable constituent of the rock, as are ostracods in K_1.

Dolomite forms the upper part of C_1, and local and subsequent dolomitization has taken place at various points in the S beds, probably by the percolation along certain divisional planes of water containing magnesium carbonate.

Fig. 3.—*Hillside between Quarries 1 & 2 and the upper part of Quarry 2.*

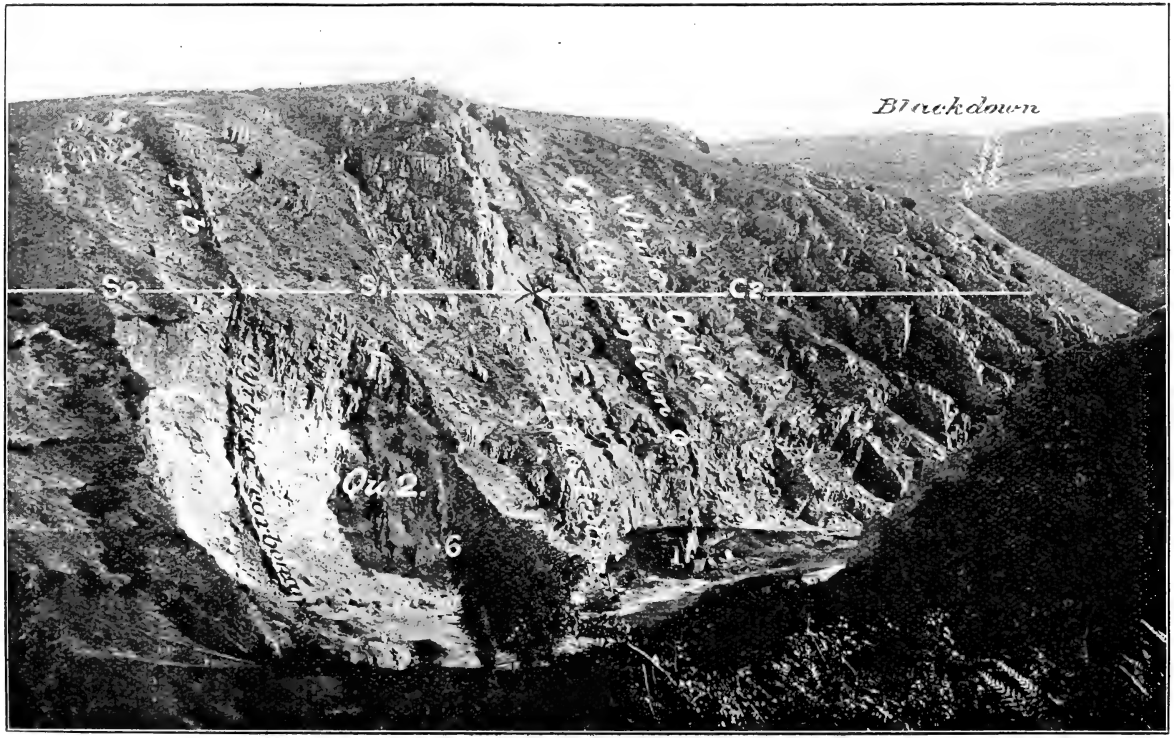


S. H. R. photogr.

Fig. 4.—*From the hillside exposure of S_2, past Quarry 2 and Plumley's Den to 'The Cave.'*

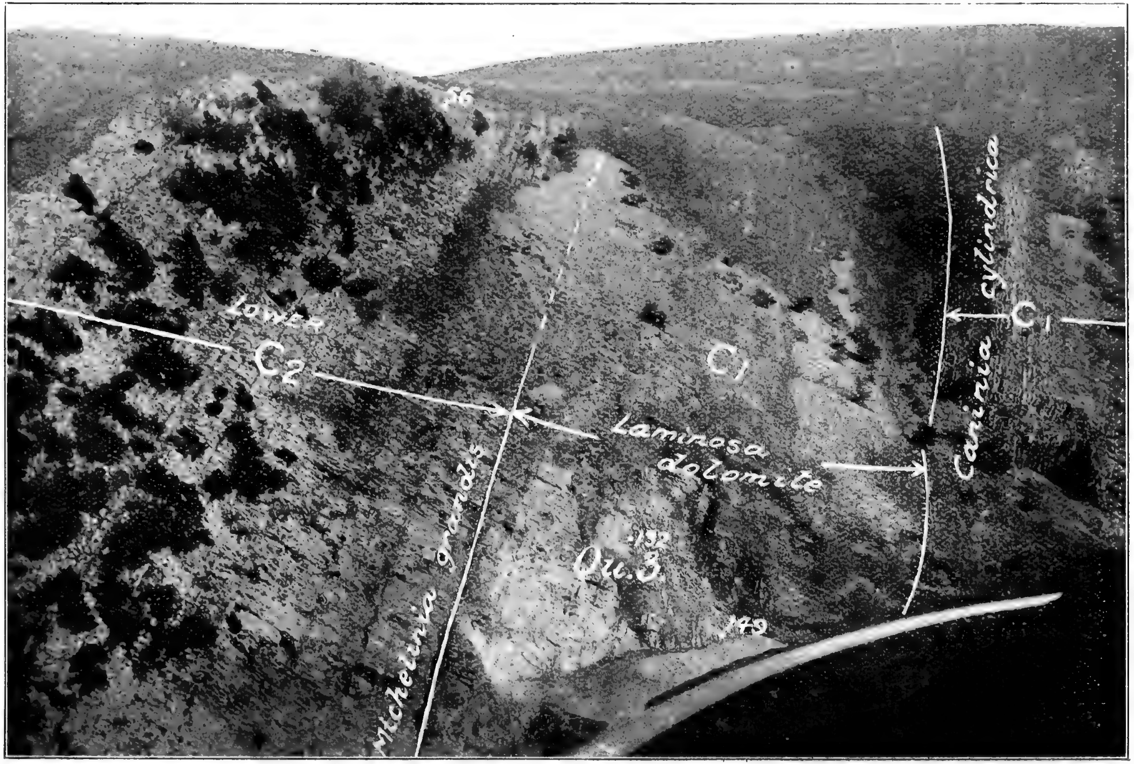
S. H. R. photogr.

Fig. 5.—S_1 and C_2 beds, from Quarry 2 to near Quarry 3.



S. H. R. photogr.

Fig. 6.—*The base of* C_2, *the dolomites of Quarry 3, and the top of* $C_1\gamma$.



S. H. R. photogr.

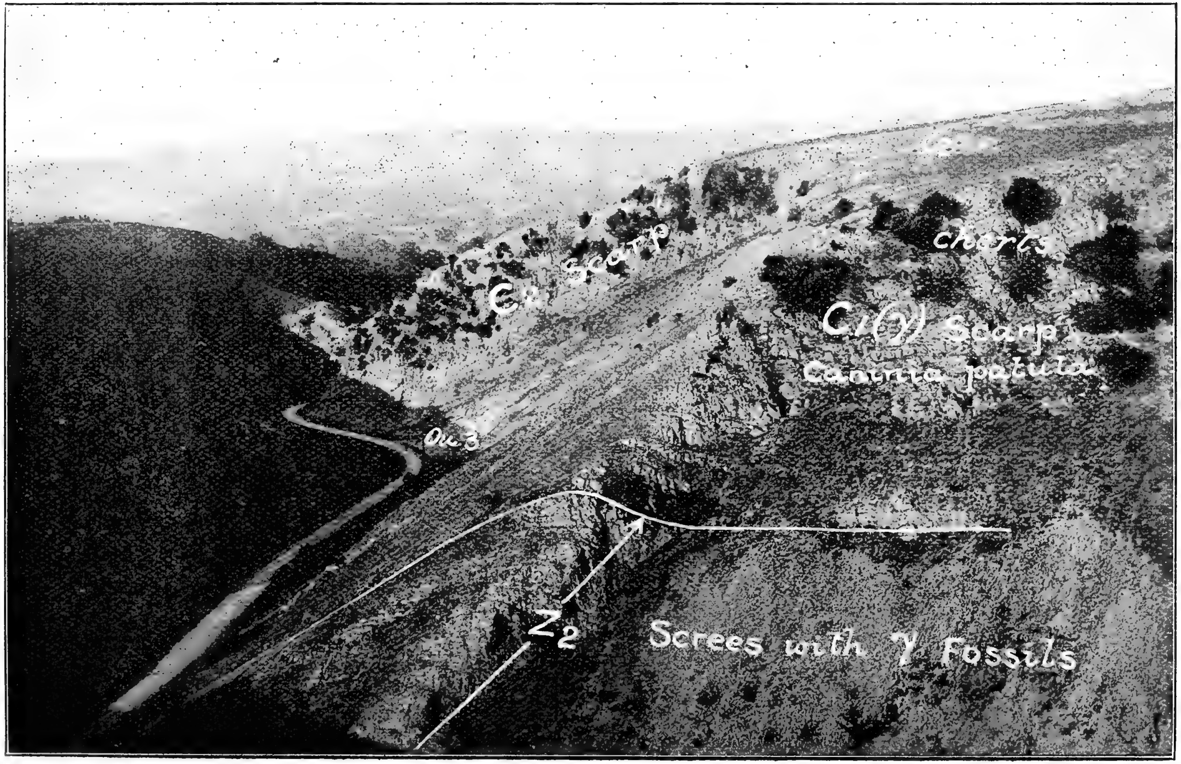
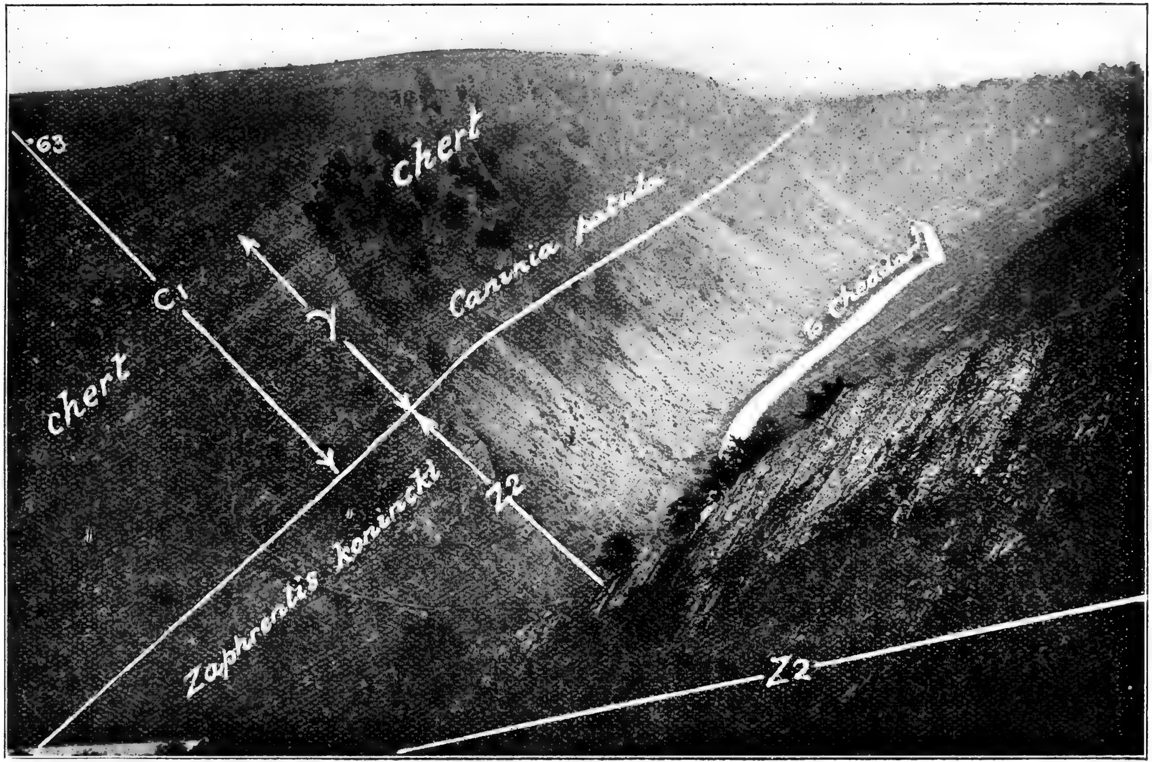


Fig. 7.—*View reversed, looking northwards. It comprises the scarp of C_2, Quarry 3, and the great scarp of $C_1\gamma$.*

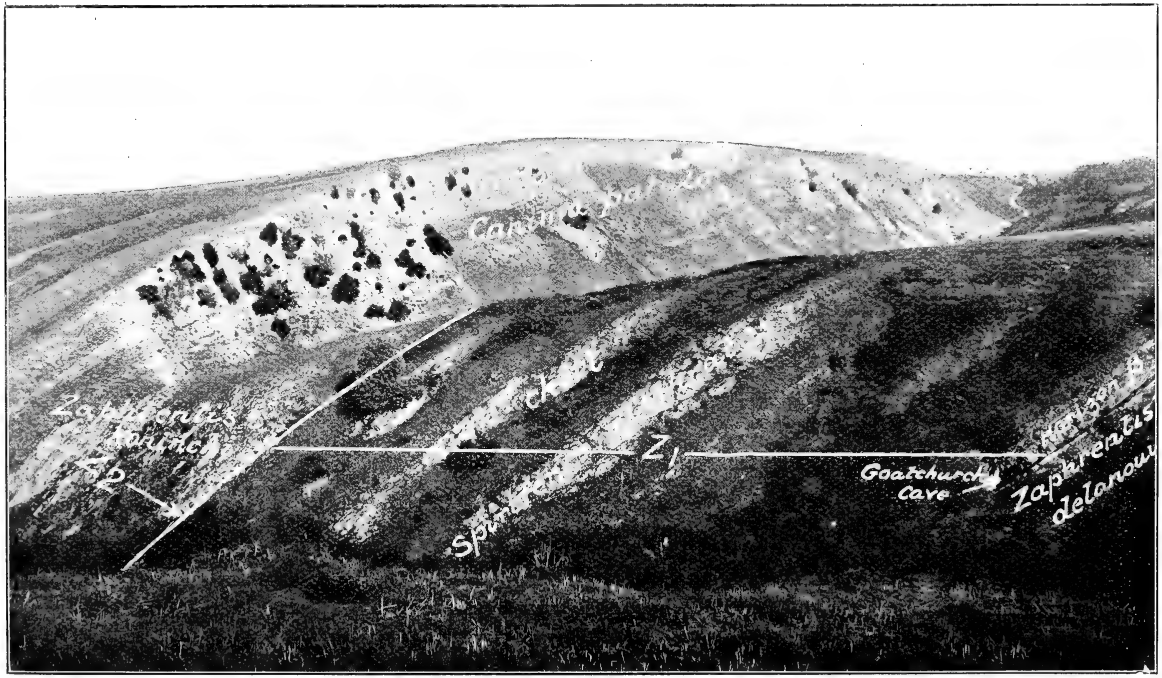
S. H. R. photogr.

Fig. 8.—*The great scarp of* $C_1\gamma$.



S. H. R. photogr.

Fig. 9.—*Valley of the western twin-stream and the great scarp beyond it.*



S. H. R. photogr.

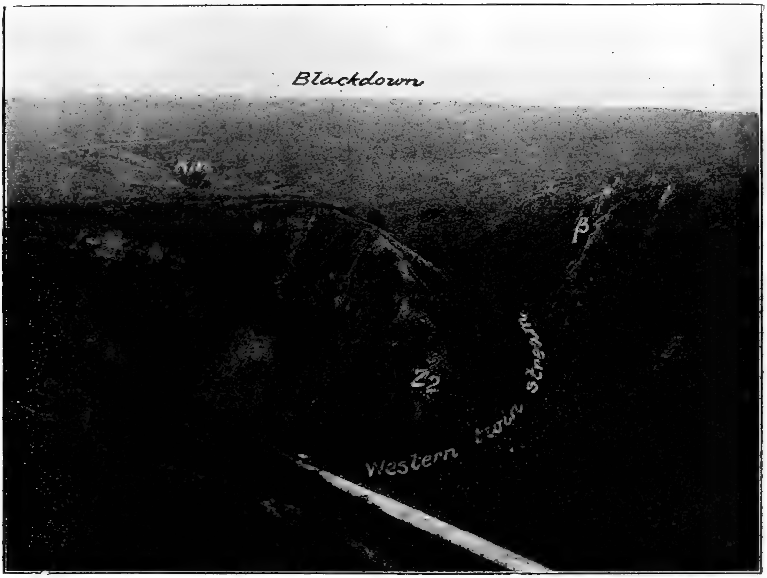
(B) Siliceous Rocks.

Chert occurs on three horizons :—

(a) At about the middle of Z_1.
(b) In the lower part of C_1, where the development is very strong.
(c) At about the middle of S_2, where again the development is very strong.

The chert, in most cases, is clearly not an original deposit, but produced by the subsequent alteration of the limestone. The corals in S_2, C_1, and Z_1 are often replaced by chert, and this sometimes takes place with the crinoids in Z, while the matrix is comparatively little affected. On the other hand, it is frequently observed, though less markedly at Burrington than at some other localities in the Mendips, such as Waterlip and Windsor Hill, that in some crinoidal limestones the matrix has been entirely replaced by chert; while the crinoid-stems have not been affected, and, having been subsequently removed by solution, are now represented by cavities. As a rule, calcitic organisms, such as crinoids, show greater relative resistance than arragonitic organisms, such as corals, whether the metasomatic change is one of dolomitization or of silicification.

Fig. 10.—*Looking up the valley of the western twin-stream.*



S. H. R. photogr.

With the exception of these cherts, siliceous rocks are not met

with anywhere in the section, except very near the base of K_1, where a definite grit-band occurs. Some of the calcareous and shaly beds at various levels in K_1 contain a good deal of sandy material.

(C) Argillaceous Rocks.

These are practically confined to :—

(*a*) The K beds, where shales are very strongly developed and contain, in places, numerous ostracods.

(*b*) Z_2 and the top of S_2, where the thin bands of limestone are separated by appreciable shaly partings.

Shaly partings occur also in connexion with the prominent rib of rock which is taken as marking the line of division between S_1 and S_2.

III. FAUNAL LISTS AND NOTES ON THE ZONAL FAUNAS.[1] (A. V.)

Note.—In §§ III & IV repetition of full references is avoided by the following abbreviations :—

'Bristol Paper' = Q. J. G. S. vol. lxi (1905) pp. 181–305 & pls. xxii–xxix—'Palæontological Sequence in the Carboniferous Limestone of the Bristol Area' by A. Vaughan.

'Rush Paper' = Q. J. G. S. vol. lxii (1906) pp. 275–322 & pls. xxix–xxx—'Carboniferous Rocks at Rush (Co. Dublin)' by C. A. Matley & A. Vaughan.

'Loughshinny Paper' = Q. J. G. S. vol. lxiv (1908) pp. 413–72 & pls. xlix–l—'Carboniferous Rocks at Loughshinny (Co. Dublin)' by C. A. Matley & A. Vaughan.

'Carruthers I' = Geol. Mag. dec. v, vol. v, Jan. 1908, pp. 20–31 & pl. iv—*Zaphrentis omaliusi*, *Z. ambigua*, and *Z. densa*.

'Carruthers II' = *ibid.* Feb. 1908, pp. 63–73 & pl. v—*Zaphrentis delanouei*, *Z. konincki*, and *Z. konincki*, mut. C_2.

'Carruthers III' = *ibid.* April 1908, pp. 158–71 & pl. vi—*Caninia cornucopiæ* and *C.* aff. *cornucopiæ*, mut. $D_{2\text{-}3}$.

These three sections are the commencement of an arduous but invaluable monograph entitled 'A Revision of some Carboniferous Corals' by R. G. Carruthers.

'Carruthers IV' = Q. J. G. S. vol. lxv (1910) pp. 523–37 & pls. xxxvi–xxxvii.

'Ed. & H.' = 'Monograph of the British Fossil Corals' by H. Milne Edwards and J. Haime, pt. iii (1852) pp. 150 *et seqq.* Palæontographical Society.

'Nouvelles Recherches' = 'Nouvelles Recherches sur les Animaux Fossiles du Terrain Carbonifère de la Belgique' Mém. Acad. Roy. Belg. vol. xxxix (1872) by L. G. de Koninck.

'Davidson' = 'Monograph of the British Fossil Brachiopoda' by T. Davidson, vol. ii (1858–63). Palæontographical Society.

---

[1] It gives me the utmost pleasure to acknowledge the very valuable assistance that Mr. R. G. Carruthers, F.G.S., of H.M. Geological Survey, has so ungrudgingly rendered in the identification and study of the Burrington corals; without his aid, the faunal lists and palæontological section would have been far less complete.

TOURNAISIAN or LOWER AVONIAN.

CLEISTOPORA ZONE (K).

K_1:

The lower portion is an Ostracod-Modiolid phase, capped by the 'Bryozoa Beds.'

The upper portion consists of normal limestone-shales.

Corals:—

None recorded.

Brachiopods:—

Chonetes cf. *buchiana* de Kon., early mutation. Very abundant at the base of the upper portion, as in the Avon section.

Chonetes cf. *laguessiana* de Kon. Abundant at certain levels in the lower portion.

Small Rhynchonellids, in part referable to *Camarotœchia mitcheldeanensis* Vaughan.

Eumetria sp. and *Productus* cf. *bassus* Vaughan are recorded by Dr. T. F. Sibly.

K_2:

Only the uppermost part of this subzone is exposed, and that badly, along the stream in Goatchurch valley.

Corals:—

Zaphrentis delanouei E. & H., Carruthers. Very rare and only at the top.

Brachiopods:—

Spiriferina cf. *octoplicata* (J. de C. Sow.). Rare.

Together with most of the species recorded below at Horizon β.

ZAPHRENTIS ZONE (Z).

Cleistopora being unknown, and *Zaphrentis delanouei* at least represented in the uppermost beds just described, it might seem logical to include the upper part of these beds in Z rather than in K; comparison, however, with neighbouring areas where the fauna is better known, together with the change of lithological character, suggest the division here adopted.

[It would be too hasty a conclusion to infer that the incoming of *Zaphrentis* was solely due to the change of conditions represented by the change of lithology; for in other localities (for instance, Llanvaches), where K and Z have a continuous lithological character, the establishment of *Zaphrentis* is delayed until approximately the same time as at Burrington. The facts point rather to a widespread and zonally-simultaneous introduction by migration.]

Horizon β (base of Z_1).

Corals:—

Michelinia favosa (Goldf.) de Kon., mut. β. Tall, narrow equal corallites.
Amplexus coralloides Sow.
Zaphrentis delanouei E. & H., Carruthers; and var. Common.
Zaphrentis cf. *parallela* Carruthers. Rare.

Brachiopods:—

Productus burlingtonensis Hall, mut. β, Vaughan.
Spirifer clathratus M'Coy, Vaughan. Abundant; the average dimensions smaller than in Z.
Spirifer ventricosus de Kon.
Syringothyris typa Winchell, Hall. Represented by small and large forms.
Syringothyris cf. *texta* Hall.
Athyris β, Vaughan.
Leptæna.
Orthotetes.

Zaphrentis delanouei, to the practical exclusion of other species, is diagnostic of the level β throughout the South-Western Province; it disappeared from that province in early Z time, never to return. The history of the gens in the Scottish Province was, however, coextensive with Avonian time, and has been dealt with by Mr. Carruthers in a recent paper.[1]

Zaphrentis vaughani Douglas has not yet been found in any part of Z in the South-Western Province—a remarkable fact, in view of the abundance of the species in Lower Z throughout the Belgian Province, and of its occurrence in beds of that age in County Clare.[2]

Z_1:

Corals:—

Syringopora θ Vaughan.
Michelinia favosa (Goldf.) de Kon.
Zaphrentis delanouei E. & H., Carruthers. Rare.
Zaphrentis omaliusi E. & H., Carruthers. Typical form only; common.

Brachiopods:—

Productus burlingtonensis Hall, mut. β Vaughan.
Productus aff. *pustulosus* Phill., early mut. Small forms; the earliest record is from β of the Avon section.
Productus cf. *semireticulatus* (Martin).
Productus cf. *niger* Gosselet: a species allied to *P. bassus* Vaughan. Rare.
Chonetes cf. *hardrensis* Phill.
Chonetes cf. *laguessiana* de Kon., Vaughan. } as interpreted in the 'Bristol Paper.' Very common.
Chonetes cf. *crassistria* M'Coy, Vaughan.
Orthis michelini (L'Éveillé) Davidson.
Orthotetes sp.: the common Z form.
Leptæna analoga (Phill.).
Spirifer clathratus M'Coy, Vaughan = *Spirifer tornacensis* de Kon. Very abundant; increasing in size.

---

[1] 'Carruthers IV.'

[2] 'The Carboniferous Limestone of County Clare (Ireland)' Q. J. G. S. vol. lxv (1909) pp. 549, 577, etc.

Syringothyris cf. *texta* Hall.
Reticularia aff. *lineata* (Martin) Vaughan: the Z form.
Athyris aff. *glabristria* (Phill.) Vaughan: lentiform. Common.

[Fishes:—*Oracanthus* spine. *Psammodus* tooth.]

Spirifer clathratus is as abundant at this level in the South-Western Province as it is in Belgium.

On the other hand, *Athyris glabristria* is, in the Belgian Province, almost entirely replaced by *A. lamellosa*.

Z_2:

Corals:—

Syringopora θ Vaughan, and a narrower variant.
Michelinia favosa (Goldf.) de Kon.: walls much thickened.
Michelinia konincki, nom. nov., including *Rhizopora tubaria* de Kon.
Michelinia megastoma (Phill.), mut. Z_2. *Cleistopora*-like aspect. Common.
Zaphrentis omaliusi E. & H., Carruthers, and its variant—*Zaphrentis densa* Carruthers.
Zaphrentis konincki E. & H., Carruthers: long narrow form. Abundant, and diagnostic of the subzone.
Endophyllum burringtonense, sp. nov. (See p. 377.)
Caninia cornucopiæ Mich., Carruthers. Common; small.
[Two rare species determined by Mr. Carruthers as *Lophophyllum* cf. *tortuosum* (Mich.) and *Amplexus* cf. *spinosus* de Kon.]

Brachiopods:—

Productus aff. *cora* d'Orb. [Recorded by Dr. T. F. Sibly.] Very rare.
Orthis michelini (L'Éveillé) Dav. Common.
Orthis resupinata (Martin). Very rare.
Orthotetes sp.: the common Z form, and a variant with stronger ornament.
Spirifer clathratus M'Coy, Vaughan. Not common.
Syringothyris laminosa (M'Coy) (Dav.): small form. Common.
Athyris aff. *glabristria* (Phill.) Vaughan: Z_2 form.

Caninia is now firmly established, although as yet represented only by small forms belonging to the typical *cornucopiæ* section; the truly vesicular groups are absent.

Zaphrentis densa is gradually replacing the more typical form of *Z. omaliusi*.

The Devonian coral, *Michelinia favosa*, finally disappears at the top of Z_2, and its place is taken by the earliest members of the megastomatid group—small, flat, plate-like ancestors with few corallites.

Dr. Sibly's record of *Productus* aff. *cora* is the earliest occurrence at Burrington of this very long-lived gens. In the Bristol area this early mutation is well known, and in the Forest of Dean the history is pushed back at least as far as β; forward, the gens can be traced into the Permo-Carboniferous.

CANINIA ZONE (C).—The MID-AVONIAN.

Horizon γ (base of C_1).

The one important change from the Z fauna is the introduction of the large vesicular Caninids. Speaking in terms of zonal time, we may say that these large Caninids suddenly and simultaneously attained dominance from the East of Belgium, across England and Wales, to the West of Ireland. In Belgium their history can be traced back with certainty to late Devonian time, but, even in this, the country of their birth, it was not until the beginning of C time that they became the most important factor of the coral fauna.

In γ at Burrington the large Caninids are associated in the main with Z_2 forms; but combined with these are a few rare, though highly interesting, ancestors of the incoming Viséan fauna.

Corals:—

Amplexus coralloides Sow., including a very large form.
Zaphrentis densa Carruthers.
Zaphrentis konincki E. & H., Carruthers.
Menophyllum tenuimarginatum E. & H., de Kon.; determined by Mr. Carruthers. Rare.
Caninia cornucopiæ Mich., Carruthers: the *cornu-bovis* stage is frequently well marked. Very common.
Endophyllum burringtonense, sp. nov.: larger forms than in Z_2.
Caninia patula Mich., Salée: a cyathophylloid Caninid. Abundant.
Caninia densa Salée.
Cyathophyllum (?) θ Vaughan; strong Caninoid affinities. Common and diagnostic of this horizon.
Cyathaxonia cornu Mich. Not common.
Clisiophyllid, an early representative of a C–S group.

Brachiopods:—

Productus aff. *punctatus* (Martin): early mutation, convergent early *Pr. scabriculus.*
Spirifer aff. *striatus* (Martin): early mutation, convergent *Sp. clathratus.*
Spirifer pinguis Sow. Rare.
Spirifer konincki Dewalque (= *Spirifer cinctus* de Kon. and auctt., non A. de Keyserling). Abundant in one band.
Athyris aff. *glabristria* (Phill.), and a variant of Seminuloid form.
Athyris aff. *lamellosa* (L'Éveillé). Not common; the dominant Athyrid in Belgium.

Cyathaxonia cornu and *Athyris lamellosa* are both greatly more abundant at γ in Belgium than in the South-Western Province; and the same remark is true of *Spirifer konincki*, which is the zonal index of these beds in Belgium, and there, as in parts of the South-Western Province, occurs also in Z_2. *Spirifer pinguis* is extremely common in the Waulsortian phase of this level and C_1, both in Belgium and in Ireland (County Dublin and County Clare).

C_1: including a lower series of γ type and an upper, dolomitic series.

Corals:—

Amplexus coralloides Sow.
Zaphrentis densa Carruthers.
Caninia cylindrica (Scouler) Salée. Abundant.

Brachiopods:—

Productus pustulosus Phillips, mut. C; large form. Common at one level.

Productus cf. *semireticulatus* (Martin): the Waulsortian form.

Papilionaceous *Chonetes*.

Chonetes cf. *comoides* (Sow.): Productoid and Leptænoid groups, the Productoid group predominating. Abundant at a certain level.

Orthis resupinata (Martin): the typical form. Abundant at one level.

Spirifer sp.: a Waulsortian form. Rare.

Syringothyris aff. *cuspidata* (Martin): the typical large C form. Common; the acme of this species is in the Waulsortian phase of this subzone.

The interest of the foregoing list lies rather in what it suggests, than in the scanty fauna which it actually enumerates.

In the abundance of large *Producti-Chonetes* and giant Caninids we can recall the '*Productus-giganteus* Beds' and 'serpent-rock' of South Pembrokeshire.

In the giant brachiopods (*Syringothyris cuspidata*, etc.), and in the long worm-like *Amplexus*, we see in very feeble outline the rich Waulsortian knolls of Belgium and Ireland.

The dividing line between Lower and Upper Avonian in the South-Western Province has, following the suggestion of Mr. E. E. L. Dixon, been shifted from its former position, at the base of S_1, to the middle of C; his argument is based upon the fact, which he has convincingly demonstrated,[1] that this was the period at which emergence gave way to subsidence in the west of the South-Western Province.

Considered from the faunal standpoint, and with our present more complete knowledge, there can be no question that the old system which involved the separation of the top of C from the bottom of S is unworkable, owing to the earlier introduction of Lithostrotions and their kin in the west of the Province.

The subjoined table (p. 368) presents the faunal ranges, as they are now known, with regard to the two lines C_1C_2 and C_2S. Mere inspection shows that the upper part of C_2 must be included with S_1, and that C_1 must lie below the separating line; but that it is immaterial from this standpoint where, within the lower part of C_2, the division between Upper and Lower Avonian is taken.

The further question of the use of the Belgian terms 'Tournaisian' and 'Viséan' to designate the Lower and Upper divisions of the Avonian, is complicated by the uncertainty of the division-line in the Belgian Province itself. As it seems, however, that the new line of division in the South-Western Province will practically coincide with the division between Tournaisian and Viséan at the base of the 'Marbre noir de Dinant,' the Belgian names can be usefully retained.[2]

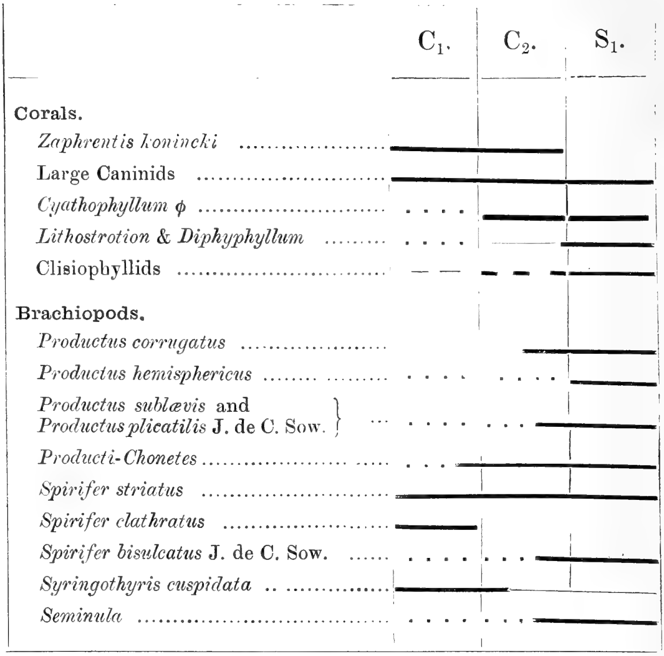
---

[1] 'Carboniferous Succession in Gower' Abs. Proc. G. S. 1909-10, pp. 72-73.

[2] See H. de Dorlodot, 'Relations entre l'Echelle Stratigraphique du Calcaire Carbonifère de la Belgique et les Zones Paléontologiques d'Arthur Vaughan, d'après les Recherches les plus récentes' Bull. Soc. belge de Géol. vol. xxiv (1910) Proc. Verb. pp. 247-90.

At Burrington the division-line between C_1 and C_2 must be placed at the top of the *laminosa* dolomites; but fossil bands are too infrequent in the dolomites at the top of C_1 and in the lower part of C_2, either to confirm or to disprove the abruptness of the faunal transition.

Ranges of Corals and Brachiopods in the Mid-Avonian of the South-Western Province.



VISÉAN or UPPER AVONIAN.

C_2:

Lower (and main) portion, up to the White Oolite.

Corals:—

Michelinia grandis M'Coy. Common.
Large Caninids. Not common.
Cyathophyllum φ Vaughan: small form, convergent *Zaphrentis konincki*, mut. C_2.
Carcinophyllum θ Vaughan?: an early mutation. A single specimen.

Brachiopods:—

Productus corrugatus M'Coy, mut. C_2. Abundant at one level.
Papilionaceous *Chonetes*.

Syringothyris cuspidata (Martin): the large C form.
Seminula cf. *ambigua* (Sow.): a distinct variant or new species. Common at a level discovered by Dr. Sibly.
Seminula ? gregaria (M'Coy) (a doubtful reference). Not uncommon.

[Gasteropods are abundant at certain levels:—*Euomphalus* and *Bellerophon.*]

We here notice the initiation of two important Viséan gentes, *Cyathophyllum* aff. *murchisoni* (represented by its progenitor *C.* ϕ) and *Carcinophyllum* θ (leading on to *Lonsdalia*), as well as the establishment of *Productus* aff. *corrugatus* and of *Seminula*; the last-named genus is represented by two peculiar species that have a greater importance in the North-Western Province—now for the first time sinking beneath the Carboniferous Sea.

C_2:

Upper portion: the White Oolite.

Corals:—

Cyathophyllum ϕ Vaughan: typical form.
Chætetes (?) tumidus (Phill.) E. & H.

Brachiopods:—

Productus corrugatus M'Coy, mut. C_2.
Productus θ Vaughan. Very abundant at the top.
Productus cf. *sublævis* de Kon. Rare.
Productus cf. *concinnus* Sow. Common.

The rare *sublævis*-like forms of *Productus* merely suggest their enormous abundance at this level in Belgium and Northern France. The White Oolite is remarkably constant in position and fauna, wherever the peculiar conditions of the *Seminula* Zone are about to follow (Belgium, Northern France, South-Western Province, North-Western Province.) In certain areas, however (as, for example, South Pembrokeshire), the whole of C_2 is faunally continuous with the *Lithostrotion* Beds above, and it is best to class C_2 and S_1 together as one division—the C–S Zone. On the other hand, in areas where the Waulsortian or knoll phase is developed (parts of Belgium and Ireland), it is often very difficult to separate C_1 from C_2.

SEMINULA ZONE (S).

S_1:

Corals:—

Lithostrotion martini E. & H. Common.
Carcinophyllum mendipense Sibly. Not uncommon.
Productus corrugato-hemisphericus: a group composed of more than one gens.
Spirifer cf. *suavis* de Kon. (?).
Athyris cf. *expansa* Dav., non (Phill.).
Athyris cf. *paradoxa* (M'Coy). Not rare: very broad fringes.
Athyris ingens de Kon.
Seminula sp. Rare.
Camarophoria isorhyncha (M'Coy). Rare.

At Burrington, where large Caninids are absent, it is not easy to distinguish S_1 from the overlying beds ; the occurrence of *Cyrtina carbonaria* (M'Coy) is here taken, for convenience, to mark the base of S_2. The lower limit of S_1 is also artificial, being taken at the first observation of *Lithostrotion.*

The assemblage:—*Athyris ingens* (= *Athyris* cf. *glabristria* Sibly), *Camarophoria isorhyncha, Carcinophyllum mendipense,* at the base of Quarry 2 suggests the Milton-Road level of Dr. Sibly's Weston paper.[1] [This assemblage is also found at Cheddar,[2] but there the level must be a little higher than at Burrington, for I have found *Cyrtina carbonaria* to be a common associate of the above-mentioned forms at Cheddar. The distance above the White Oolite in the two cases tends to confirm this view.]

S_2: the main *Seminula* Zone.

Corals:—

Cyathophyllum aff. *murchisoni* E. & H.: an aberrant and rare variant.
Lithostrotion martini E. & H. Abundant.
Carcinophyllum θ Vaughan. Common.

Brachiopods:—

Productus θ Vaughan. At the bottom.
Productus corrugato-hemisphericus, including *Pr. cora,* mut. S_2, Vaughan. Common.
Papilionaceous *Chonetes.* Common.
Seminula ficoides Vaughan. Common throughout.
Cyrtina carbonaria (M'Coy). Common only at the bottom, but ranges through.
Productus giganteus (Martin), mut. D_1. Only at the top.

The *Seminula* fauna is very limited in species, but remarkably abundant in individuals; bands composed almost entirely of *Lithostrotion, Productus, Chonetes* or *Seminula,* succeed each other and repeatedly recur through the zone. Considering how exclusive this fauna is, it is remarkable how widely it is spread, for it is the standard fauna of this period in Belgium and Britain, and we do not yet know its phasal equivalents.

DIBUNOPHYLLUM ZONE (D).

D_1: the only part of the zone uncovered at Burrington.

Corals:—

Cyathophyllum murchisoni E. & H. Abundant.
Diphyphyllum sp., convergent *Koninckophyllum* θ Vaughan.
Dibunophyllum φ Vaughan. Common.

Brachiopods:—

Productus giganteus (Mart.), D_1 mut.
Productus hemisphericus J. de C. Sow. Abundant.
'*Orthotetes*' cf. *senilis* (Phill.).
Athyris cf. *expansa* Dav., non (Phill.), mut. D_1.

---

[1] Q. J. G. S. vol. lxi (1905) p. 560.
[2] *Ibid.* vol. lxii (1906) p. 357.

This fauna agrees with that of D_1 at all other points of the South-Western Province, and is closely similar to that of the same level in the North-Western Province near the top of the Great Scar Limestone. It is, in fact, astonishing how close is the resemblance of the South-Western and North-Western Provinces at this horizon.

D_2:

This division—the top of the Carboniferous Limestone in the Bristol Area—is covered by Triassic rocks in the syncline between Burrington and Wrington, but must be continuous with the fine exposure of fossiliferous beds in the quarry overlooking Wrington. The fauna of these beds is described in the 'Bristol Paper'.[1] These beds may be correlated with the top of the Great Scar in the North-Western Province, where they are capped by the Yoredales, to which, in the South-Western Province, there is no fossiliferous equivalent except in Gower.[2]

IV. PALÆONTOLOGY. (A. V.)

(1) CORALS.

Michelinia.

The two forms of greatest interest both occur in Z_2.

MICHELINIA MEGASTOMA (Phill.), mut. Z_2.

This form has as yet no specific name, although its abundance in many, and widely separated, districts at the same level makes it an important zonal fossil.

The corallum is circular with a flattened base; the calicinal surface is gently convex.

The corallites have large, approximately equal, apertures, and are some ten in number.

The walls of the calices are thick and almost vertical; the calices are deep, so that there is little room between floor and epitheca for the development of vesicular tissue, and the internal structure is almost entirely concealed by the growth of stereoplasm.

The epitheca is concentrically wrinkled, without roots.

This mutation is common in Z_2 at Burrington, Stackpole Quay, Malahide, etc.

There can be little doubt that this mutation passes up into the typical *M. megastoma*, a species that has its maximum in C–S, and only differs from the Z mutation in greater size and in the proportionately larger number of corallites.

The *megastoma* beds of Rush (C–S) contain the typical *M. megastoma* in abundance.

At Burrington the place of *M. megastoma* is taken by *M. grandis*, and the rule seems to be generally true that *M. megastoma* and *M. grandis* are, to a considerable extent, mutually exclusive.

---

[1] Q. J. G. S. vol. lxi (1905) p. 242.

[2] Abs. Proc. Geol. Soc. 1909–10, pp. 72–73.

MICHELINIA KONINCKI, nom. nov. (A single corallite is figured—Pl. XXXI, fig. 4.)

= *M. grandis*, mut. Z.
= *M. tenuisepta* Ed. & H. and de Kon., non (Phill.).

This species is the most distinctive of all the Michelinias, and is splendidly figured by de Koninck (as *M. tenuisepta*)[1]; Ed. & H. pl. xliv, fig. 1 is also a good representation.

The tall corallites are few in number; their apertures are large, and do not differ very markedly in size.

These two characters distinguish the species immediately from *M. tenuisepta* (Phill.), figured by me in the Loughshinny paper, p. 456. I have consequently assigned to it a new specific name.

The corallites, on account of their slight adhesion, are commonly found separate—a vertical section of one of these isolated tubes is figured in Pl. XXXI, fig. 4, and shows the vesicular structure of *Michelinia*.

M. konincki probably passes up into *M. grandis* M'Coy, a tall, large-apertured species abundant in C–S. *M. grandis* is not uncommon in C_2 at Burrington; it abounds in the North-Western Province at Arnside, Kendal, etc., and it was from this province that the type-specimen was derived.

Zaphrentis.

ZAPHRENTIS DELANOUEI Ed. & H., Carruthers.

Identical with 'Carruthers II' pl. v, fig. 6.

At Burrington this species is abundant at β and rare in Z_1; there is no record of its occurrence above this level at any point of the South-Western Province. It occurs in Z–γ, both at Malahide and at Tournai. I have no personal knowledge of its occurrence in the Viséan, although a form transitional towards *Z. enniskilleni* is found in C-S of Arnside.

ZAPHRENTIS cf. PARALLELA Carruthers. (Pl. XXX, figs. 1 *a*–1 *b* & (?) figs. 3 *a*–3 *b*.)

Compare 'Carruthers IV' pl. xxxvii, figs. 4 *a*–4 *d*.

This form is larger and more regularly conical than the abundant and typical *Z. delanouei*, with which it is associated.

The fossula in the adult (fig. 1 *b*) is remarkably parallel-sided and contracts at the apex—*cf.* Carruthers's fig. 4 *a*; the septation is, however, more Caninoid than in his figures.

[Figs. 3 *a* & 3 *b* are sections of a coral closely similar, externally, to the above, but much mineralized by beekite; it is possible that this may be a *Caninia*, although comparison with figs. 1 *a* & 1 *b* suggests that it is merely a badly-preserved example of *Z.* cf. *parallela*.]

The species is rare in β, at Burrington, where I do not know it at any other level.

---

[1] 'Nouvelles Recherches' pl. xiii, figs. 2 & 2 *a*.

ZAPHRENTIS OMALIUSI Ed. & H., Carruthers.

Identical with 'Carruthers I' pl. iv, figs. 1–4.

At Burrington this species is abundant in Z_2, not uncommon in Z_1 and at γ, but has not been found above γ.

In the South-Western Province generally, *Z. omaliusi* enters as a very small and very rare form in β; in Z_1 it is not uncommon; it abounds in Z_2 and γ, and ranges on into C_1.

Neither here nor elsewhere do I know of the occurrence of the typical species in rocks of Viséan age.

ZAPHRENTIS DENSA Carruthers. (Pl. XXX, fig. 2.)

'Carruthers I' pl. iv, figs. 7 & 8.

At Burrington, *Z. densa* is rare in Z_2, equally common with *Z. omaliusi* at γ, and common, after the disappearance of that species, in C_1 above γ.

Our figure compares well with Carruthers's fig. 7, and is a horizontal section of a typical specimen from C_1, just below the dolomite.

The passage of *Z. omaliusi* into *Z. densa*, suggested by Carruthers, is an established fact at Burrington and in the South-Western Province generally.

ZAPHRENTIS KONINCKI Ed. & H., Carruthers.

'Carruthers II' pl. v, figs. 1–4 *a*.

At Burrington this species, in a narrow, cylindro-cornute form, abounds in Z_2 and is common at γ, but has not been found at any higher level. A specimen from the base of Z_2 has shorter minor septa.

No example of the C_2 mutation, convergent with *Cyathophyllum* ϕ, has yet been discovered at Burrington, although common at many points of the South-Western Province, at Arnside, etc.

Caninia.

The following species of *Caninia* are represented at Burrington, at the levels stated:—

Caninia cornucopiæ Mich., Carruthers—Z_2 and γ.
C. patula Mich., Salée—γ.
C. cylindrica (Scouler) Salée—C_1.

CANINIA CORNUCOPIÆ Mich., Carruthers.

Refer to 'Carruthers III.'

Mr. Carruthers has given so excellent an account of this species that my notes need be but brief.

At Burrington the species enters in Z_2, is abundant at γ with *C. patula*, but disappears before the incoming of *C. cylindrica*.

In Z_2, only the *Zaphrentis* stage is exhibited; at γ, the amplexoid, or '*cornu-bovis*' stage is not infrequently observed. At no point of

the South-Western Province did *C. cornucopiæ* ever attain the large size or abundance that makes this species so important an index of Z_2–C_1 throughout the Belgian Province. Dr. Salée records the species from Z_1 (Calcaire de Landelies), where it is not common.

CANINIA PATULA Mich. (Pl. XXX, figs. 5 *a*–6 *b* & text-fig. 11.)

H. Michelin, 'Iconogr. Zooph.' 1840–47, p. 255 & pl. lix, fig. 4.
L. G. De Koninck, 'Nouvelles Recherches' p. 87 & pl. viii, fig. 2 (*Zaphrentis patula*).
A. Salée, 'Le Genre *Caninia*' Brussels 1910, p. 39 & pls. vi–viii.

Externally, our specimens accord best with Michelin's figure, except that minor septa are not visible within the calyx as in his type-figure. In this respect, L. G. de Koninck's figured calyx exactly resembles the few specimens that I have been able to collect with well-preserved calices. Since Dr. Salée, of Louvain University, has given so detailed a description of this species, and has illustrated it by such a wealth of figures, there will be no need to do more than note a few peculiarities of the Burrington specimens.

This species is characterized by its fossula, wide vesicular ring, and septa continuous to the walls (so that no peripheral zone of large vesicles is developed). The septa are, at least partly, thickened by stereoplasm; this thickening affects all the septa in the young (see Pl. XXX, fig. 5 *a*), the two cardinal quadrants only (see fig. 6 *a*), or is limited to a lining of the fossula (see fig. 5 *b*). In a region of thickened septa there is an inner wall, formed of thickened arcs stretching from septum to septum; this is usually absent on the counter-fossular side.

There are at Burrington two forms or varieties, which differ only in degree; they may be defined as widely and closely septate respectively. The widely-septate form is the abundant one, and is represented in Pl. XXX, figs. 5 *a* & 5 *b*. Fig. 5 *a* shows the young stage, in which vesicles are undeveloped, the septa are thickened throughout, and the counter-septum is elongated. Fig. 5 *b* is an adult, in which stereoplasm is practically absent, and the vesicular ring is remarkably Cyathophylloid. It is worthy of note that vesicles first form on the counter-side, so that the ring is much wider on this side (see text-fig. 11, p. 375).

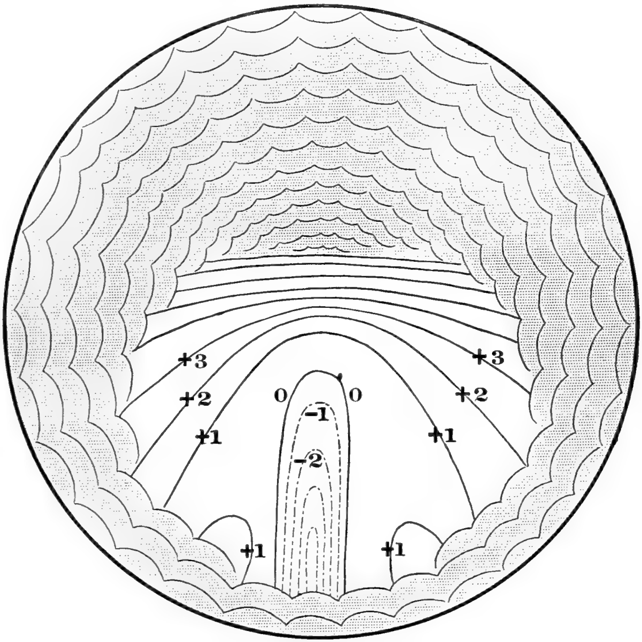
Minor septa are undeveloped, either in this or in the closely-septate variety, and herein lies the main difference from all the specimens figured by Salée; it may be that this difference is mutational.

Figs. 6 *a* & 6 *b* represent the closely-septate form, which is chiefly remarkable for a curious flexure of the tabulæ; this peculiarity is indeed met with in the widely-septate form also, but is there less common. A contoured plan of such a tabula is represented in text-fig. 11 (p. 375), from which the general character is obvious:—A narrow, flat-bottomed fossular valley is bounded laterally by almost vertical walls and behind by a steep slope; having ascended this slope we find ourselves on a broad, flat plane. Proceeding towards the north across this plane, we encounter a second steep bank that

abuts sharply against a vertical wall, built up of vertically elongated vesicles (represented diagrammatically in the figure).

As might be anticipated from the uniplanar curvature, the symmetry of the young cornute stage is essentially bilateral; on the other hand, that of the adult cylindrical stage tends to become radial.

Fig. 11.—*Contoured plan of one of the characteristic tabulæ of* Caninia patula, *Mich.* × *2·7 diameters.* (*Drawn from silicified specimens occurring in γ at Burrington Combe.*)



[The outer ring of vesicles is diagrammatically shown, and the septa are omitted.]

The ranging of this gens under *Caninia* rather than under *Cyathophyllum* is a matter of personal preference, for it cannot be maintained that so typical a *Cyathophyllum* as *C. murchisoni* does not occasionally exhibit both a distinct fossula and stereoplasmic thickening. The most characteristic feature, however, of *Cyathophyllum*—the presence of a marginal ring of small vesicles within the central area—is lacking in *Caninia patula*. On the other hand, the development of an amplexoid stage—so distinctive a feature of *Caninia cornucopiæ*—is also lacking in *Caninia patula*.

It is impossible to consider *C. patula* to have been derived from either *C. cornucopiæ* or *C. cylindrica*, and in my opinion its marked peculiarities warrant the creation of a new genus.

Occurrence.—At Burrington, and at other points of the South-Western Province that have been carefully revised, *Caninia patula*, in the mutation (?) that has no minor septa, is diagnostic of γ.

In Belgium the typical *Caninia patula* ranges to my personal knowledge through C_1, but I have seen it nowhere else. (The precise horizon of Dr. Salée's figured specimens is not stated.)

It is possible that *C. bristolensis* Vaughan (= *C. cylindrica*, mut. S_1 Vaughan) may be a member of the gens *C.* aff. *patula* as suggested by Dr. Salée (*op. cit.* p. 33); *C. bristolensis* has, however, the following very marked characters that ally it with *C. cylindrica* mut. C_2, and distinguish it from *C. patula* :—

(1) The septa are strongly developed only within the inner wall, and are all much thickened in the adult stage.
(2) The prolongations of the septa through the vesicular area are very irregular in their course and very faintly developed, suggesting late acquisition of the structure.
(3) These prolongations are, in places, discontinuous; and in such regions large vesicles are developed, resembling those of *C. cylindrica.*
(4) The minor septa project inwards beyond the vesicular ring as short teeth thickened by stereoplasm, exactly as in *C. cylindrica.*
(5) The vesicular ring is composed of an inner zone of fine, closely-packed vesicles, and a broader outer zone of coarse irregular structure.

In confirmation of his suggestion Dr. Salée remarks (p. 46, *op. cit.*) that he has never observed, in any coral, the acquisition of small vesicles following a stage characterized by large ones. This contention is, however, definitely disproved in the case of *Caninia cylindrica* mut. C_2, where the transition is clearly demonstrable (see below, under *C. cylindrica*).

CANINIA CYLINDRICA (Scouler) Salée. (Pl. XXXI, fig. 1.)

A. Salée, 'Le Genre *Caninia*' Brussels 1910, pp. 27–39 & pls. ii–iv.

Dr. Salée has given so excellent an account of this species, and has illustrated it by such majestic figures, that I have contented myself with a single figure showing the highest stage of development reached in C_1 at Burrington—the only level, at that place, at which the species is known with certainty.

The earlier stages are exactly as figured by Dr. Salée in pl. iii of his monograph, namely :—

(1) A '*cornucopiæ*' stage—strong bilateral symmetry, no vesicles, short minor septa, pennant-like majors.
(2) A '*cornu-bovis*' or amplexoid stage—short thickened majors and short minors, broad central tabular area, peripheral vesicles irregularly developed at thickened rings and absent at constrictions.
(3) '*cylindrica*, mut. γ' stage—septa, both major and minor, prolonged outwards for a short distance from the inner wall so as to produce a narrow 'external' area, beyond which they extend discontinuously as projections from the large peripheral vesicles (see Pl. XXXI, fig. 1).

In C_2 and later forms in other parts of the South-Western Province, mutation proceeds simultaneously along two lines :—

(*a*) The septal prolongations extend from inner to outer walls, traversing the whole vesicular area.
(*b*) The fossula becomes diminishingly conspicuous, with the result that a Campophylloid stage is acquired.

No specimens illustrating this mutation have been found at Burrington, where *Caninia* is not definitely known above C_1.

It is interesting to point out that in Belgium, where the gens probably originated, stage 2 (*v.s.*) is the highest stage reached in Z_1 (Calcaire de Landelies).

Endophyllum priscum (Münster) Frech,[1] from the lower part of the Upper Devonian, is a Caninid that reaches the stage 2. The early stages, however, of this coral resemble those of the next described species, and it cannot therefore be regarded as a member of the gens of *C. cylindrica*.

It is interesting to notice that similar stages in coral development can be observed in other gentes not closely related to *Caninia cylindrica*. In fact, the four stages of development:—

(1) Septa without vesicles;
(2) Endophylloid stage—large peripheral vesicles, septa not prolonged outwards;
(3) '*cylindrica*' stage—septa produced outwards for a short distance only, large peripheral vesicles;
(4) Septa produced to wall;

are well exhibited in the *Carcinophyllum-Lonsdalia* progression:—

Stages
(1 & 2) Zaphrentoid *Carcinophyllum*—major and minor septa thickened at wall so as to be in contact, large peripheral vesicles present only at certain levels. *C. mendipense* from C–S.

Stage
(2) *Carcinophyllum* typical—major and minor septa projecting from a thickened inner wall, peripheral vesicles always present, septa not produced outwards. *Carcinophyllum* θ from S_2 and D_1.
(Compare Pl. XXXI, fig. 5—a specimen from the lower part of S_2.)

Stage
(3) '*Lonsdalia* cf. *floriformis*' types—inner wall formed of fine crowded vesicles, septa prolonged outwards for a short distance, forming a narrow 'external' area; large peripheral area. *Lonsdalia floriformis* from D_2.

We may also note that *Carcinophyllum* is essentially a simple coral (I have only seen two compound specimens in a long experience), whereas *Lonsdalia* is essentially compound, illustrating the general law that compound forms are preceded by simple ancestors.[2]

Endophyllum Ed. & H., Frech.

Zeitschr. Deutsch. Geol. Gesellsch. vol. xxxvii (1885) p. 76.

ENDOPHYLLUM BURRINGTONENSE, sp. nov. (Pl. XXX, figs. 4 *a*–4 *c*.)

Irregularly-bent, vermiform coral with strong annular thickenings.

The major septa are thickened only at the wall and do not reach the centre, but leave a clear central area occupied by tabulæ

---

[1] Zeitschr. Deutsch. Geol. Gesellsch. vol. xxxvii (1885) p. 76, pl. vii, fig. 2 & pl. x, figs. 2, 2 *a–c*.

[2] See Rep. Brit. Assoc. 1909 (Winnipeg) p. 191.

alone. A third of the septal ring is composed of a group of straight, longer septa which do not meet one another; the remaining two-thirds of the ring are formed of shorter curved septa, that meet internally to build up a continuous inner boundary to the septal ring.

Minor septa are practically absent in the young stage (Pl. XXX, fig. 4 *a*), but in later stages (fig. 4 *b*) they become a conspicuous and diagnostic feature; at the rim of the calyx they equal in prominence the majors.

The tabulæ occasionally stretch completely across the vertical section without interosculation; but the majority of the tabulæ split, so as to form broad cushion-like vesicles (Pl. XXX, fig. 4 *c*). All the tabulæ bend down at the wall.

Vesicles are developed only in the adult stage, and especially at the thickened rings and on the convex side (fig. 4 *c*—the vesicles present on the convex side have been accidentally blocked out in the print); these vesicles are vertically elongated, and shift the septal base-line inwards.

In the absence of the earliest stage, which is probably cornute, the position of the fossula is difficult to fix; it probably lay opposite the longer septa, although the tabulæ are apparently depressed on that side.

Comparison with *Amplexus cornu-arietis* de Kon.

'Nouvelles Recherches' p. 72 & pl. vi, figs. 4, 4 *a*.

The external characters—form and calyx—of the Burrington species present a strong general resemblance to L. G. de Koninck's figures, although it is difficult to believe that his figures are both views of the same specimen. In his description at p. 72 of the text, that author mentions a deep fossula—a fact that immediately separates his species from ours, and suggests that Mr. Carruthers is right in including *Amplexus cornu-arietis* as a synonym of *Caninia cornucopiæ*.

Comparison with *Endophyllum priscum* (Münster) Frech.

The cross-section of the young stage of *E. priscum*[1] is almost identical with fig. 4 *a* of our Pl. XXX, and the tabulæ are of the same nature.

The development of vertically-elongated peripheral vesicles in the adult is on the same plan as in our species—although the degree of development is very much greater in Prof. Frech's figure, and separates the two forms specifically.

The habit that the septa often show in *E. priscum*, of leaning against one another, is also exhibited in certain adult sections of *E. burringtonense*.

There can be no question that *E. burringtonense* and *E. priscum* are distinct species of the same genus.

---

[1] Zeitschr. Deutsch. Geol. Gesellsch. vol. xxxvii (1885) pl. x, fig. 2.

Occurrence.—*Endophyllum burringtonense* occurs in Z_2 and γ at Burrington, and the γ forms are markedly larger than those from Z_2. The same form occurs in the Rush Slates of County Dublin and in γ of Malahide.

Cyathophyllum.

CYATHOPHYLLUM (?) θ Vaughan. (Pl. XXXI, fig. 2: a calicular view.)

A horizontal section of a young form is figured in the Bristol Paper, pl. xxiii, fig. 2. It is much easier to describe this striking coral than to assign it to a particular genus.

In the adult, there is an external ring of fine vesicles, crossed by equally distinct major and minor septa.

The major septa extend to the centre, where they become flexuous, and one of them is strengthened to form a conspicuous ridge.

The walls of the calyx descend steeply from a sharp rim; the floor of the calyx is vaulted in the middle to form a tall conical peak, crested by the strengthened septum. As remarked above, the long septa climb this peak somewhat spirally.

The earliest stage has no vesicles and presents a Caninoid type of septation.

The fossula is strongly developed at all stages on the *Caninia*-like plan.

As a mere description, *Cyathophyllum* appears to be more satisfactory than *Caninia*, since it implies the actual plan of the septation and the biseptate external ring of vesicles; furthermore, *Cyathophyllum murchisoni* frequently exhibits a fossula precisely like that of our species. That the species had a Caninoid ancestor seems, however, clear.

The elevation of the peak is extremely variable, though always noticeable. The external form is a typical, wide-angled horn, and the epitheca is nearly smooth. The vertical section shows clearly the incoming of the vesicles, at some little distance from the tip.

This species occurs at only one level within γ. I know it from other points of the South-Western Province, but never from any other horizon; it is common at Burrington.

I owe the fine figured calyx to Mr. H. F. Barke, of Bristol, who extracted the coral from a mass of limestone by immersion in acid.

CYATHOPHYLLUM MURCHISONI Ed. & H. (Pl. XXXI, fig. 6.)

This section suggests relationship to the *Diphyphyllum* figured in the same Plate (fig. 7); but the resemblance is deceptive and accidental. The two rings of fine vesicles separated by a ring of more open texture, are at once determinative of *Cyathophyllum*, and the central tabulate area is an abnormality confined to a portion only of the individual. This kind of abnormality is even commoner in the simple forms of *Cyathophyllum regium*, in which there are

normally no tabulæ. Such a phenomenon may perhaps find a parallel in the unwinding of the most highly-developed ammonites.

The specimen is from the upper part of S_2.

Diphyphyllum.

DIPHYPHYLLUM sp. (Pl. XXXI, fig. 7.)

It is difficult to decide to which of the following genera to refer this fine coral:—

Campophyllum Ed. & H., emend. Carruthers.
Koninckophyllum Nich. & Thoms.
Lophophyllum Ed. & H., emend. Carruthers.
Diphyphyllum M'Coy, emend. Vaughan.

Campophyllum is never columellate.

Koninckophyllum is best confined to strongly columellate forms, with a thick external area made up of closely-packed vesicles, and with minor septa projecting (as in *Lithostrotion*) beyond the vesicular ring.

Lophophyllum, as figured by Mr. Carruthers,[1] differs very markedly from our species in the insignificance of the minor septa and in the highly-developed central structure in the adult.

Our form is practically non-columellate, although consecutive tabulæ are occasionally ridged in the centre, when a crest is formed which reaches from tabula to tabula. This phenomenon is highly characteristic of *Diphyphyllum*, to which genus I have referred the species.

It is not unlikely that our form is a direct descendant of *Diphyphyllum subibicinum* (M'Coy), a species which has its maximum in C–S and ranges through S; variation must be assumed to have resulted in increased thickness and packing of the external ring, and in the occasional ridging of the tabulæ.

The Burrington form occurs at D_1, and is convergent with *Koninckophyllum* θ.

Clisiophyllid.

An early CLISIOPHYLLID. (Pl. XXXI, fig. 3.)

The central area is composed of a thick plate, surrounded by three or four strong concentric intersections which are crossed by short, thin, discontinuous lamellæ.

The major septa are thick and moderately spaced. The minor septa are equally thick, short but prominent. All the septa are attached to the wall by their thickened ends, and practically no vesicles are developed.

Judging from similar forms in C and C–S, the columella with its thin coating of vesicles projected as a tall, laterally compressed

---

[1] 'A Carboniferous Fauna from Nowaja Semlja . . . . . with Notes on the Corals by R. G. Carruthers' Trans. Roy. Soc. Edinb. vol. xlvii (1909) pp. 152 *et seqq.* pl. i, figs. 1–2 *d*.

spike from the floor of the calyx. (Very similar forms are known from C–S of the South-Western Province, the North-Western Province—Arnside, etc., County Dublin, etc.)

The figured section agrees well with fig. 2 *a*, pl. xxx of the Rush Paper from C–S [1] (Rush Conglomerate or *megastoma* beds), and possibly our species is actually an earlier member of the same gens; the only essential difference consists in the fact that a thin external ring of vesicles is developed in the Rush species, and is absent from our Burrington form.

The figured specimen was found at γ; its damaged state prevented me from founding a new species.

(2) BRACHIOPODS.

Chonetes.

I. The small *Chonetes* of the Lower Tournaisian:—

Chonetes cf. *buchiana.*	As interpreted in the Bristol Paper.
Chonetes cf. *crassistria.*	
Chonetes cf. *hardrensis.*	
Chonetes cf. *laguessiana.*	

(The degree of approximation denoted by 'cf.' is, in all four cases, one of general aspect only.)

CHONETES cf. BUCHIANA is figured by Davidson ('Dav.' pl. lv, fig. 12).

Shell small, convex, non-transverse; ribs coarse and often forked at the margin. A concentric ornament composed of minute folds, which is still seen in the under layer, but is not usually impressed on the cast.

The resemblance to *Ch. buchiana* de Kon. of the Upper Viséan (D) consists solely in the similarity of ribbing; the D species is transverse, with a broad rolled beak.

It is necessary, therefore, to separate this form from *Chonetes buchiana* under a new specific name; I propose *Ch. stoddarti*, in commemoration of the late W. W. Stoddart, of Bristol, who collected the specimens studied by Davidson.

Occurrence.—This species appears to be very local in its distribution, for it only occurs abundantly in the Avon and at Burrington. It is only known in K_1.

---

[1] In the Rush Paper (pp. 276–77) the following correlation of the continuous sequence—Rush Slates, Rush Conglomerate or *megastoma* beds, Carlyan Limestone—was made:—

Carlyan Limestone and *megastoma* beds.	C_2–S_1.
Rush Slates	Z_2–C_1.

Although this correlation was called in question (pp. 441–42) in the subsequent or Loughshinny Paper, it has now been amply confirmed and the apparent difficulties explained.

CHONETES cf. CRASSISTRIA is figured in pl. xxvi, fig. 2 of the Bristol Paper.

This small *Chonetes* has the general form and convexity of *Ch.* cf. *hardrensis*, but differs in the strength and spacing of its ribs. There is a fine concentric striation that, in the more coarsely-ribbed forms, is as obvious as in *Ch. stoddarti.*

Occurrence.—Common in K and Z_1 of many localities in the South-Western Province, but rare at Burrington.

CHONETES cf. HARDRENSIS Phill., Dav. ('Dav.' pl. xlvii, fig. 22.)

Shell small, convex, non-transverse, and finely ribbed, with a small number of hinge-spines.

Distinguished with difficulty from small *Chonetes* that are abundant in Upper D of the North of England and Scotland.

At Burrington, as in the South-Western Province generally, this species crowds the surfaces of beds in Z_1 and occurs more rarely in the Upper Tournaisian; it is practically absent from the Viséan.

CHONETES cf. LAGUESSIANA is figured in pl. xxvi, fig. 1 of the Bristol Paper.

Shell flattened, transverse, rectangular, finely and closely ribbed.

Cardinal region almost perfectly flat; the rest of the surface very gently flexed. Cardinal spines numerous.

Occurrence at Burrington.—Abundant at certain levels in K_1 and common in Z_1.

II. The large *Chonetes* of the Upper Tournaisian:—

CHONETES cf. COMOIDES of the Bristol Paper includes two distinct forms, agreeing in large size and massiveness with *Chonetes comoides* Sow.

(1) A large Productoid form, excusably confused with *Productus giganteus.*

The muscular field of the convex valve is that of *Chonetes,* and not of *Productus*; there are no accessory adductors as in *Daviesiella.*

The development of this giant *Chonetes* seems to have been carried out within the South-Western Province, for there is continuous increase in size and convexity (but essential agreement in other traits) onward from Z_1, where the gens is first recognized.

The Z_1 mutation is rare, but conspicuously larger than the abundant *Ch.* cf. *hardrensis*; it is essentially distinct in form from *Ch.* cf. *laguessiana.*

There is of necessity some difficulty in unravelling the history of the gens below Z_1, for further diminution of size would result in a small form so like *Ch.* cf. *hardrensis* as to require most minute discrimination.

Occurrence at Burrington.—Common at the bottom of the C_1 dolomite, and at the same level in the South-Western Province generally.

(2) A large geniculate (Leptænoid) form with a flat cardinal region.

The form that has just been described has a strongly convex beak and beak-region; the present form is equally large and even more massive, but has a flat cardinal region occupying half the valve, the rest of the valve being gently flexed. The shell is markedly transverse.

Although the immediate ancestors of this form are unknown, it is not improbable that *Chonetes* cf. *laguessiana* is an early ancestor, for reduction in size and massiveness by parallel development with the first-described form would result in just such an ancestor as *Ch.* cf. *laguessiana*.

Occurrence.—The development of this Leptænoid form was probably carried out in the Pembroke area, where it reaches its greatest abundance; it becomes less abundant when traced eastwards, and, in Belgium, the discovery of a rare example was recorded and described by M. P. Destinez.[1]

At Burrington this form is a rare associate of the Productoid form described above. In other parts of the South-Western Province it is, as already stated, much commoner, and reaches its acme in C_2.

The Relation between **Syringothyris** and **Spiriferina**.

SYRINGOTHYRIS LAMINOSA (auctt.) non (M'Coy). (Pl. XXXI, fig. 8.)

Spiriferina laminosa de Kon., Ann. Mus. Roy. Hist. Nat. Belg. vol. xiv, pt. 6 (1887) pp. 103–105 & pl. xxii, figs. 44–50, pl. xxx, figs. 30–31.

Range.—Z_2 and C_1.

External characters.—The general aspect is that of a large *Spiriferina*, with a well-developed area and coarse ribs. As in *Spiriferina*, there is a delthyrial callus extending for a short distance only from the apex. The shell is punctate, as in both *Spiriferina* and *Syringothyris*.

Internal characters.—Wholly or partly buried within this callus is an infilled syrinx that can be seen half projecting along the middle line of the callus and, in weathered specimens, is represented at the apex by a short narrow rod.

A cross-section near the beak shows the infilled syrinx and the two dental plates; at a little distance below the beak the strong mesial septum begins to appear.

In these two characters:—

(1) The presence of a syrinx,
(2) The late development of a mesial septum,

consists the claim of the species to belong to *Syringothyris*.

Comparison with the genotype of *Spiriferina*.—A cross-section of *Spiriferina rostrata*, from the Middle Lias, at the beak shows the absence of a syrinx and the immediate appearance of the mesial septum.

---

[1] Ann. Soc. géol. Belg. vol. xxix (1901–1902) Bull. p. 106.

Comparison with *Syringothyris subconica* (Mart.), from the D Zone.—*S. subconica* is so similar to *S. laminosa* that its specific separation has been viewed with scepticism. There seems, indeed, to be no reasonable doubt that *S. subconica* is the direct descendant of *S. laminosa*, and differs only in the accentuation of traits already adumbrated in the earlier form.

A cross-section of the beak of *S. subconica* reveals the characters of *Syringothyris* as typically developed as in *S. cuspidata* (Mart.) itself. Hence *S. laminosa* develops, phylogenetically, into a typical *Syringothyris*.

The problem consequently seemed to have been satisfactorily solved, and the separation of *Spiriferina* from *Syringothyris* was reduced to the rubbing down of the beak :—

If the mesial septum appears at once, without a trace of syrinx :—
Spiriferina.
If the mesial septum is delayed, and there is at least a primitive syrinx :—
Syringothyris.

Comparison with Carboniferous 'Spiriferinas' has reopened the problem. This investigation is as yet incomplete, but the results obtained indicate the close relationship in Carboniferous time of the two genera *Spiriferina* and *Syringothyris*. For example :—

In *Spiriferina octoplicata* (J. de C. Sow.), which is common in the D Zone, the appearance of the mesial septum is retarded, and there are Syringothyroid characters in the cross-section.

In *Spiriferina peracuta* de Kon., common in early Z in Belgium, the mesial septum is a mere ridge. (The cross-section has not yet been studied.)

The most probable guess is, that *Spiriferina* and *Syringothyris* were both derived, at much the same time, from a common ancestral group, and that they developed on different lines, but that, in the earliest period of their history, they possessed the same essential structure.

The figured specimen, from γ of Burrington, shows the syrinx on the rubbed-down beak.

History.—An early mutation occurs at β (see below); *S. subconica* is the D mutation.

SPIRIFERINA cf. OCTOPLICATA (J. de C. Sow.), Vaughan, 'Bristol Paper' pl. xxvi, fig. 6.

Occurrence.—K and β of the South-Western Province; rare at Burrington in K_2.

The small shells included under this head, from the South-Western Province, probably comprise two species :—

(1) An early mutation of *Syringothyris laminosa*, discussed above. Compare figure of young form, de Kon. *op. cit.* pl. xxii, figs. 49–50.

This completes the history of the gens *S. laminosa* in the Avonian.

(2) *Spiriferina peracuta* de Kon. *op. cit.* pp. 101–102 & pl. xxii, figs. 56–61.

This species is very abundant in Z_1 of Belgium; the specimen figured in the Bristol Paper is probably the same.

Comparison with *Spiriferina octoplicata* (J. de C. Sow.).—*Sp. peracuta* has tall and narrow ribs, the furrows being relatively broad; so that a cross-section of a single valve lying on its ribs is castellated with narrow slits. The cardinal angles are never rounded, and the hinge-line is the greatest width of the shell.

Sp. octoplicata has ribs and furrows equal and similarly angular, so that the cross-section, made as above, is sharply maxillate. The hinge-line is often shorter than the width of the shell, and the cardinal angles are then rounded.

The history of *Spiriferina* in the Avonian is as yet unknown.

V. (*a*) PHYSIOGRAPHICAL COMPARISON OF THE BURRINGTON SEQUENCE WITH THAT AT OTHER POINTS OF THE SOUTH-WESTERN AND BELGIAN PROVINCES. (A. V.)

These two provinces may be considered to form together a single large province, to which the name Bristol-Dinant Province will be applied.

Pre-Avonian. (Old Red Sandstone.)

Burrington, in common with the whole South-Western Province, formed part of a great inland lake, whereas the Belgian Province and North Devon were covered by the Devonian Sea.

Km.

In the South-Western Province, fresh water gave place to very shallow marine conditions.

In the Belgian Province, the sea became shallow. Hence in Km conditions became similar over the whole Bristol-Dinant Province.

In North Devon a Carboniferous fauna was evolving in the *Productella-productoides* Beds of the Pilton Series.

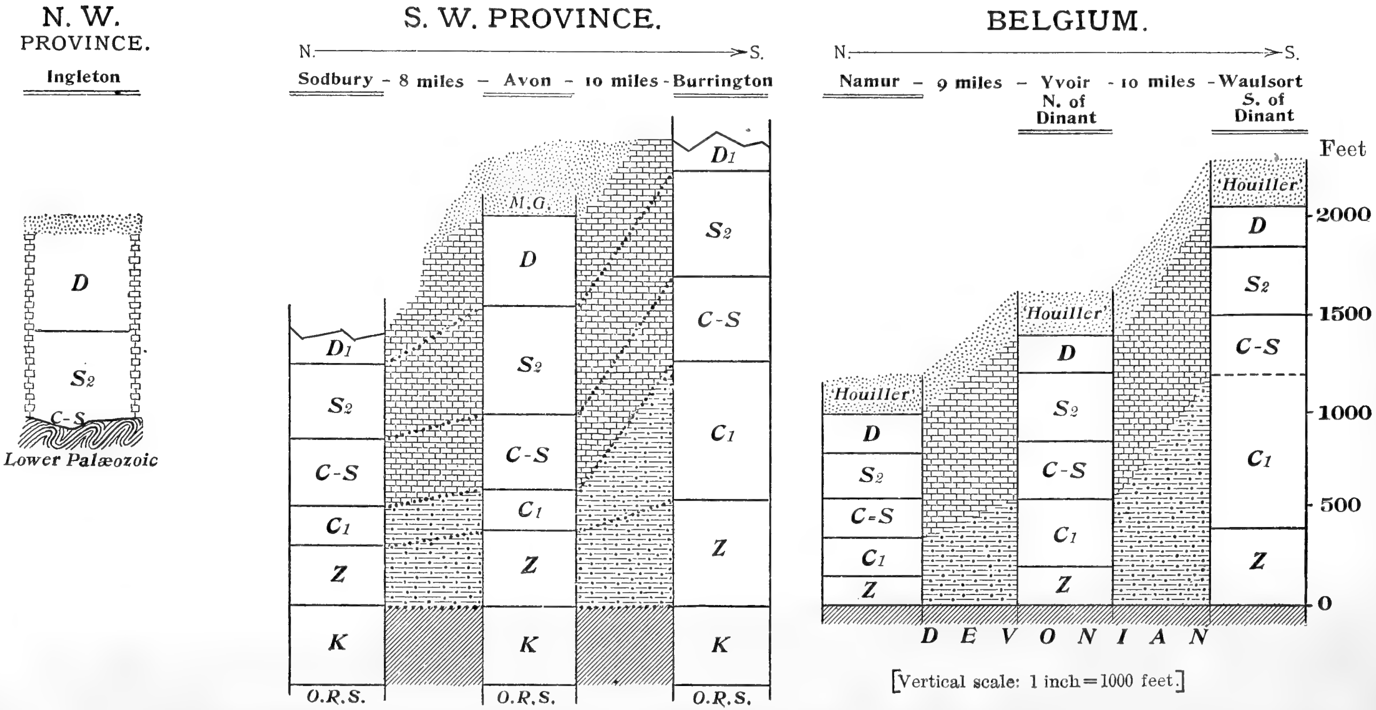
This is the base-line of the Avonian and the bottom of the *Cleistopora* Zone.

K_1 and K_2.

The Carboniferous fauna became established throughout the South-Western Province, whereas Km conditions persisted in the Belgian Province.

This portion of the sequence is consequently classed as Carboniferous in England, but as Devonian in Belgium. Since it is a matter of impossibility to separate our K beds from Z under two distinct formations, whereas it is merely a conventional division in Belgium, we may hope that the young Belgian geologists will come into line.

Fig. 12.—*The relation of Burrington to other Carboniferous Limestone districts.*



It is worthy of note that the thickness of K traced northwards from Burrington does not diminish as it does in later zones, on account doubtless of different configuration of the shore-line.

β (base of Z).

Standard conditions (encrinital limestones and shales) became continuous over the whole Bristol-Dinant Province, and the *Zaphrentis* fauna was established.

In the uppermost Pilton Beds of North Devon, the fauna is essentially a β fauna with a few persistent Devonian forms.

This is the period of greatest extent of the Bristol-Dinant Province, and has been selected as the datum-line for the vertical sections in fig. 12 (p. 386).

It is the base-line of the Belgian Carboniferous and of the Tournaisian of the Belgian writers (an unfortunate fact, since we cannot therefore in strictness include the K zone in the Tournaisian).

Z.

Standard conditions prevailed generally over the Bristol-Dinant Province, and there is a noticeable diminution of thickness both towards the north from Burrington and Dinant, and towards the east from the South-Western Province to that of Belgium. Furthermore, North Devon emerged, and formed the southern boundary of the Bristol-Dinant Bay. The variation of thickness clearly points to a northern and eastern shore.

[The disproportionate thickening of Z at Burrington and Waulsort is caused by the oncoming of C_1 conditions (see below) at the top of Z.]

Dolomite is developed towards the northern and eastern shorelines (for instance, nearly the whole of Z is dolomitized in the Chepstow area north of Burrington, and in the Namur area north of Dinant).

C_1.

Indications of a shallowing sea are universal throughout the Bristol-Dinant Province, and this is the period of greatest diversity of deposit.

Two types of deposit dominate the sediments, namely:—

(1) The coarsely-crinoidal or 'Petit-Granit' type, with the knoll or Waulsortian type as a variant;
(2) Dolomite.

At Burrington there is a great thickness (625 feet) of the Petit-Granit type followed by dolomite (375 feet).

Unfortunately, only the lowest and highest parts of the Petit-Granit division are well exposed. At Waterlip, however (south of Burrington and on the southern flank of the Mendips), where the development is practically identical in thickness with that at Burrington and agrees exactly where the two series can be compared,

the rocks have been extensively quarried. Besides beds made up almost entirely of crinoidal débris, there are many levels at which deposits of a knoll-like nature can be observed, although the most characteristic features of Waulsortian rocks are apparently absent.

At Waulsort, the knoll type is magnificently developed, and at Écaussines there is an equally fine display of the typical[1] Petit Granit.

That deposits of this type were rapidly accumulated is clearly shown in fig. 12 (p. 386) by the disproportionate expansion of C_1 at Burrington and at Waulsort.

The Dolomite.

As we pass northwards from Burrington or Dinant, dolomites gradually replace the lower, Petit Granit division, until the whole of C_1 is represented by dolomite, as in the case of the Grande Dolomie of Namur. The consequent diminution in thickness is strikingly brought out in fig. 12.

The Viséan (C–S, S and D).

Since we are only concerned here with differences within the Bristol-Dinant Province, there is no need to dwell upon the Viséan sequence, for the deposits are remarkably similar at the same levels throughout the Province. There is a diminution in thickness of each zone northwards and eastwards as in the Tournaisian, and doubtless due to the same cause. In D of the South-Western Province, Clisiophyllids are abundant at all points; in Belgium, however, corals are rare except between Liége and Dinant. (They are, nevertheless, abundant in the North-East of France near Avesnes.)

[In the foregoing account I have omitted all reference to Visé, at which corals of D species abound; the Visé limestone is an example of the British Midland type, unique so far as Belgium is concerned; it rests unconformably upon, or is faulted against, typical Devonian.]

For comparison with the Bristol-Dinant Province, a vertical section of the Ingleborough sequence is included in fig. 12 (the data were kindly furnished by Mr. Cosmo Johns). This section illustrates the two points in which the North-Western Province differs from the South-Western, namely:—

(1) The omission of lower zones—here the Tournaisian is wanting.
(2) The expansion of D—here due to the development of Yoredales.

---

[1] Prof. H. de Dorlodot, of Louvain University, restricts the term Petit Granit to a deposit made up of large crinoid-fragments embedded in a matrix of smaller fragments, with the further condition that the deposits must be of C_1 age. I have ventured to use the term in a broader sense, for rocks made up almost entirely of large crinoid-fragments, even though their matrix be in part a fine calcareous mud.

(*b*) COMPARISON OF THE UPPER PALÆOZOIC CORALS WITH THE LOWER PALÆOZOIC GRAPTOLITES, IN REGARD TO OCCURRENCE, DISTRIBUTION, AND EVOLUTION. (A. V.)

(i) The coral and graptolite-bearing beds, respectively limestones and mudstones, in their typical development build up rock-masses of great thickness and lithological uniformity—the layers that are actually fossiliferous forming but a small proportion of the whole mass. Both coral-limestones and graptolite-shales can alike occur intercalated in a series of typically arenaceous deposits; and, furthermore, both groups of fossils are occasionally found in indisputably shallow-water deposits.

(ii) Corals and graptolites share the disadvantage of being rare or absent in certain types of deposit.

(iii) Within each successive zone, certain genera of corals are of world-wide distribution, and the time taken to bring about this geographical expansion was, reckoned zonally, insignificant.

Of such widespread genera we may notice:—*Zaphrentis*, *Lithostrotion*, and the Clisiophyllids (both simple and compound).

As examples of the zonal contemporaneity of faunal history we may cite the following:—

Lithostrotion (both massive and dendroid) enters in the early Viséan in North America, Britain, and Belgium.

Lonsdalia characterizes the uppermost Viséan of Tian-Shan, Belgium, and Britain.

The coral indices occur in the same order wherever they are known; and, in the majority of cases, knowledge of the zonal series in one area will unravel the succession in another. As examples may be cited the coral sequences in Belgium, Northern France, the South-Western Province, and the area described by Prof. Garwood.

The truth of these statements when applied to graptolites has long been recognized and utilized, since it was first pointed out in the classical publications of Charles Lapworth.

(iv) If, however, of two zonal stratigraphers, working independently in two different areas, each drew up the series of zonal indices best suited to his own area, the two series would probably differ in two particulars, namely:—

(1) The number of zones would differ according to the variability or uniformity of the rocks and, in rough proportion to this factor, according to the extent of the area studied.

(2) The actual indices employed would differ specifically, although the genera employed would usually be in accord.

These facts are patent in the case of the graptolites, if we compare the zones suggested for Bohemia, Scania, Lakeland, North Wales, and South Wales.

In the case of the corals it is sufficient to examine the time-scales drawn up by Prof. Garwood and myself.

(v) Evolution.—It is evident that, when the history of all the dominant gentes of any fossil group has been definitely established, the co-occurrence of known mutations of several of these gentes

places the age of a bed beyond dispute—this is, indeed, the one impregnable method of zoning.

In the case of the Carboniferous corals, a splendid start has been made by Mr. Carruthers, and, in this paper, I point out the main stations along some other important lines of coral evolution.

Among the graptolites Dr. Marr, followed by Miss Elles, has pointed out several evolutionary lines which have a striking probability; the suggested series, however, await the confirmation that can only be assured by the determination of the ratios which two successive mutations bear to each other numerically, from the date of earliest occurrence of the second mutation up to the time when it entirely replaces the first.

(vi) The lines of evolution in the graptolites and in the Palæozoic corals.—As has been explained by Dr. Marr, the graptolites progressed along two directions and in two stages:—

(1) by the numerical reduction of similar parts;
(2) by the increase of structural complexity in the remaining parts.

This method of evolution is strictly comparable with that of mammalian dentition.

Furthermore, the greatest 'generic' variation took place during early periods. Again this agrees with the case of the early Tertiary mammals.

In the Palæozoic corals, viewed broadly and as a whole, the first stage finds a parallel in the reduction of fossulæ resulting in the development of radial from quadrantal symmetry. The second stage is, however, the most important in the case of the corals, for structural complexity, at the end of the Lower Carboniferous, rose to a high pitch, resulting in a maze of so-called genera among the Clisiophyllids.

Thus, in the graptolites, the greatest 'generic' variation took place at the beginning of their history—in the corals, at the end.

Reviewing all the foregoing facts, we see that extensive distribution and constancy of zonal sequence are characters shared alike by corals and by graptolites—both lowly organisms. Furthermore, the corals with which we are concerned inhabited a narrow strip along the shore-line: adult, the animal was sessile; young, it was at the mercy of currents, and it is at this stage that migration was rapidly effected.

The commonly accepted view that graptolites, either of themselves or as passengers, lived in the open sea seems to need stronger testimony than has yet been adduced, especially in view of the fact that rapidity of variation is a phenomenon usually associated rather with the fluctuating conditions of in-shore life, than with the monotonous sameness of oceanic existence.

FIG. 1.

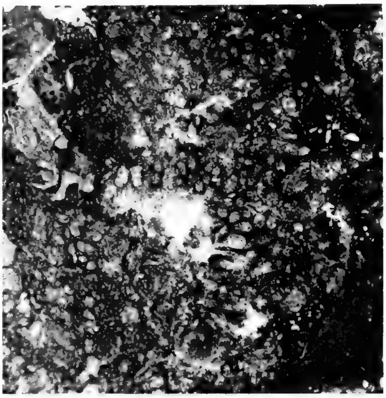


FIG. 2.

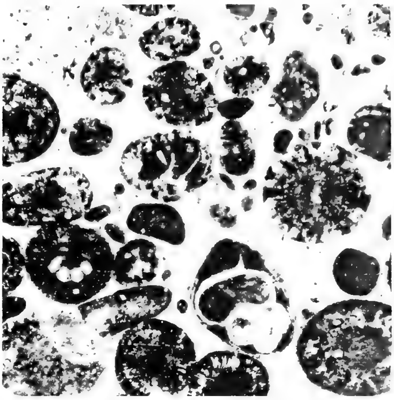


FIG. 3.

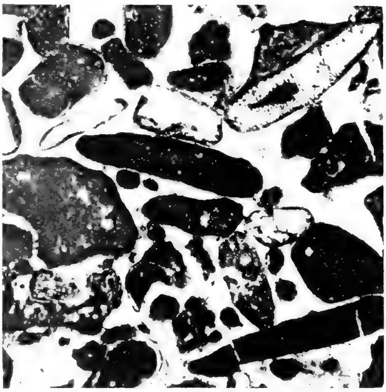


FIG. 4.

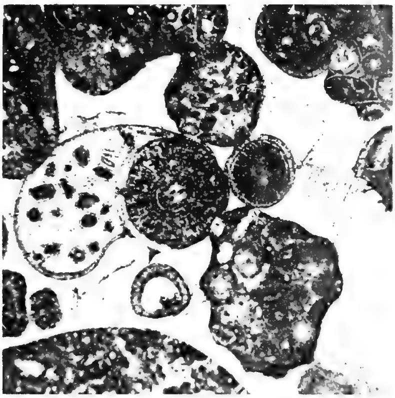


FIG. 5.

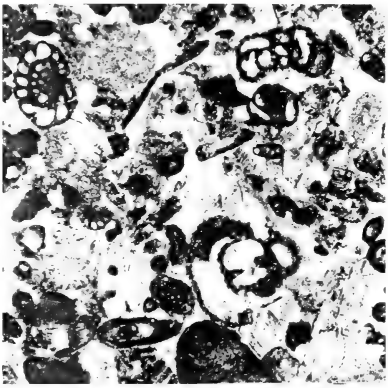
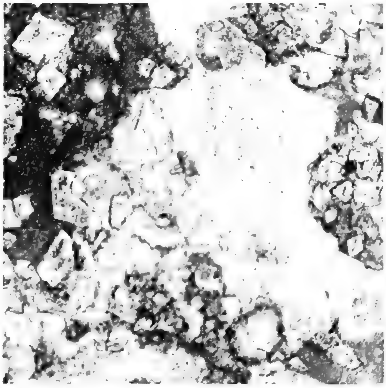


FIG. 6.



S. H. R., Photo.]

[*Bemrose Collo.*

AVONIAN OF BURRINGTON COMBE.

FIG. 1.

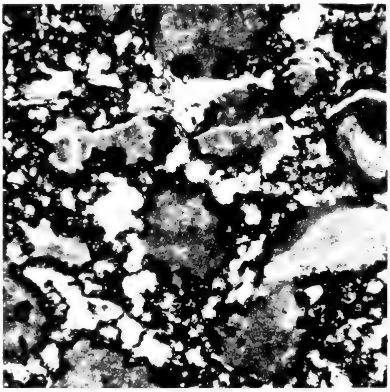


FIG. 2.

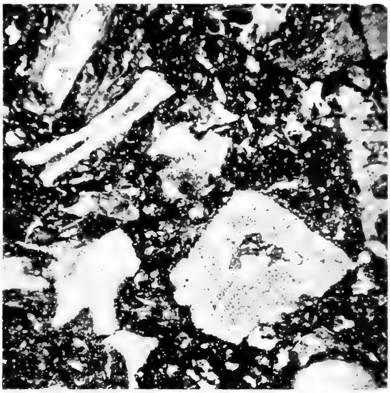


FIG. 3.

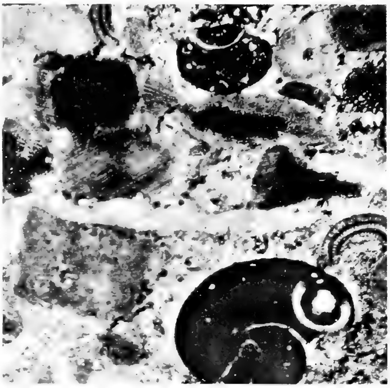


FIG. 4.

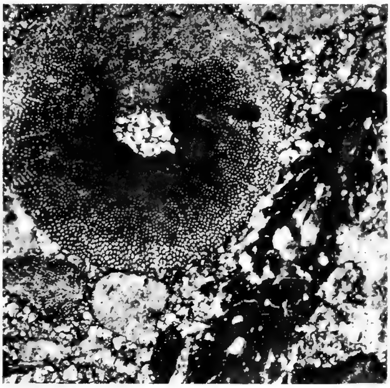


FIG. 5.

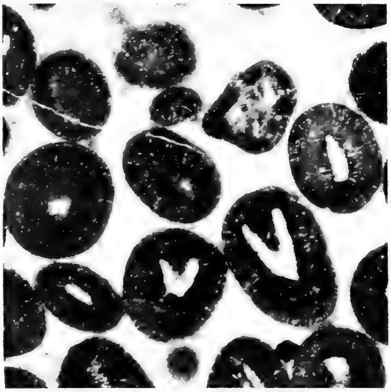
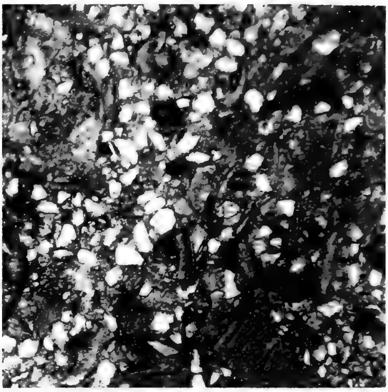
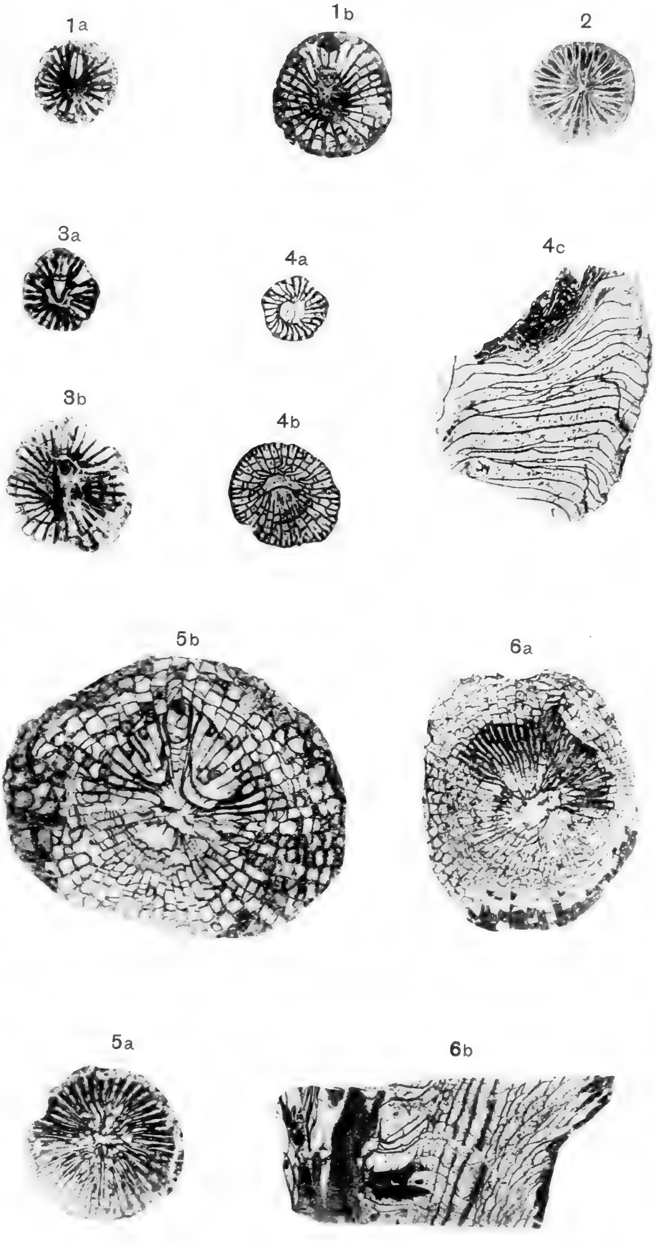


FIG. 6.



S. H. R., Photo.] [*Bemrose Collo.*

AVONIAN OF BURRINGTON COMBE.

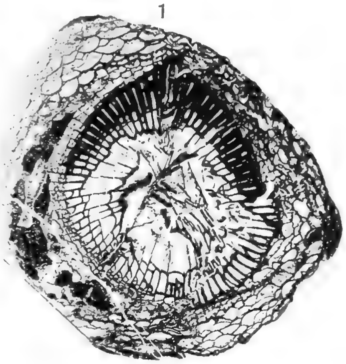


J. W. Tutcher, Photo.
Bemrose Ltd., Collo., Derby.

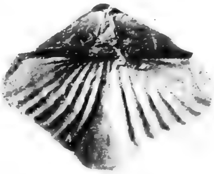
AVONIAN CORALS FROM THE BURRINGTON SECTION (MENDIP).
(ALL FIGURES MAGNIFIED 1¼.)

2

1



8



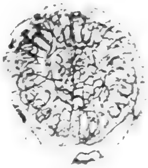
4

x 1½

3

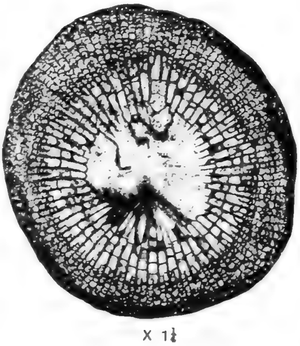
x 1½

5



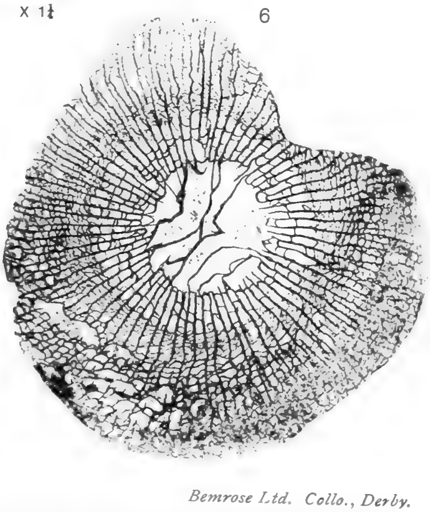
x 1½

7



x 1½

6



J. W. Tutcher, Photo.

Bemrose Ltd. Collo., Derby.

AVONIAN CORALS FROM THE BURRINGTON SECTION (MENDIP), WITH ONE BRACHIOPOD.

EXPLANATION OF PLATES XXVIII–XXXI.

PLATE XXVIII.

[Fig. 6 is magnified about 25 diameters, and all the others about 15.]

Fig. 1. Concretionary limestone showing what appear to be interlacing tubules (? calcareous alga) (31). S_2 top; Quarry 1. (See p. 345.)
2. Oolitic and foraminiferal limestone (33). S_2 top; Quarry 1. (See p. 345.)
3. Penecontemporaneously brecciated horny limestone (20). S_2; hillside between Quarries 1 & 2. (See p. 346.)
4. Penecontemparaneously brecciated oolitic and foraminiferal limestone (3). S_2 base; Quarry 2. (See p. 347.)
5. Foraminiferal and crinoidal limestone (12). C_2; near the Cave. (See p. 348.)
6. Limestone in process of dolomitization (132). C_1; Quarry 3. (See p. 348.)

PLATE XXIX.

[Fig. 6 is magnified about 25 diameters, all the others about 15.]

Fig. 1. Limestone in process of dolomitization (149). C_1; Quarry 3. The unaltered limestone is grey, the dolomite black in the photograph. The white patches are holes in the rock-slice due to faulty preparation. (See p. 348.)
2. Crinoidal limestone ('Petit Granit') (63). C_1; hillside between Quarry 3 and the Great Scarp. (See p. 349.)
3. Crinoidal limestone with gastropods (124). K_2; western twin-stream. (See p. 351.)
4. Crinoidal and bryozoan limestone ('Bryozoa Bed') (140). K_1; eastern twin-stream. (See p. 352.)
5. Coarse oolite (139). K_1; eastern twin-stream. (See p. 352.)
6. Calcareous grit with ostracods (126). K_1; western twin-stream. (See p. 352.)

PLATE XXX.

[All the figured specimens are from the Burrington section, and are magnified 1¼ times.]

Figs. 1 *a* & 1 *b*. Sections from the same specimen. *Zaphrentis* cf. *parallela* Carruthers (p. 372). From Horizon β.
Fig. 2. *Zaphrentis densa* Carruthers (p. 373). From C_1.
Figs. 3 *a* & 3 *b*. Sections from the same specimen *? Caninia* sp. or *? Zaphrentis* cf. *parallela* (p. 372). From Horizon β.
Figs. 4 *a*–4 *c*. *Endophyllum burringtonense* sp. nov. (p. 377); fig. 4 *a*, the small form from Z_2; figs. 4 *b* & 4 *c*, from Horizon γ.
Figs. 5 *a* & 5 *b*. *Caninia patula* Mich., de Kon., & Salée (p. 374). The widely-septate form. From Horizon γ.
Figs. 6 *a* & 6 *b*. *Caninia patula* Mich., var. (p. 375; see also text-fig. 11, p. 375). The closely-septate form. From the base of Horizon γ.

PLATE XXXI.

[All the figured specimens are from the Burrington section Figs. 1, 2, and 6 are of the natural size; the others are magnified 1¼ times.]

Fig. 1. *Caninia cylindrica* (Scouler) Salée (p. 376). From C_1.
2. *Cyathophyllum (?)* ϑ Vaughan (p. 379). From Horizon γ.
3. Early Clisiophyllid (p. 380). From Horizon γ.

Fig. 4. *Michelinia konincki* nom. nov. = *M. tenuisepta* de Kon., non (Phill.) (p. 372). The vertical section of a disconnected corallite from Z_2.

5. *Carcinophyllum θ* Vaughan (p. 377). From the lower part of S_2.
6. *Cyathophyllum* aff. *murchisoni* E. & H. (p. 379). An aberrant variant from the top of S_2.
7. *Diphyphyllum* sp., convergent *Koninckophyllum θ* (p. 380). From D_1.
8. *Syringothyris laminosa* (de Kon.), non (M'Coy) (p. 383). From Horizon γ.

Discussion.

Dr. T. F. Sibly congratulated the Authors on their detailed revision of this magnificent section. In the description of the section published by him in 1905, the faunal divisions recognized were substantially those maintained in Dr. Vaughan's Bristol paper. But later researches had greatly modified that original classification, and certain alterations were very conspicuous in the case of this section. He drew special attention to the change in the delimitation of Zones Z & C. Horizon γ, as originally defined by Dr. Vaughan, was characterized by the abundance of *Caninia cylindrica*, and was recognized as an horizon of faunal overlap between the two zones. But this horizon, so clearly defined in the Burrington sequence, was now placed high up in C_1, the designation 'Horizon γ' being transferred to a much lower level characterized by *Caninia patula.* At the same time, Zone C became greatly expanded at the expense of Z.

With reference to the *Seminula* Zone, and the relatively very small thickness of S_1 as here defined by the Authors, the speaker enquired what was the precise evidence relied on for separating S_1 from S_2. This zone was much better displayed in the Cheddar Gorge than at Burrington. At Cheddar, only 2 or 3 miles distant, a typical S_1 fauna occurred some 300 feet above the base of the zone, and S_1 was little, if at all, inferior in thickness to S_2. A remarkable fact, in his opinion, was that this Upper S_1 horizon at Cheddar showed a strong development of chert and an abundance of *Lithostrotion martini* in silicified masses, features identical with those of certain beds in the Burrington section included by the Authors in their S_2.

With regard to the generic position of '*Syringothyris*' *laminosa*, he mentioned that he had recently collected some well-preserved internal casts of this shell from C in the Mitcheldean district. These specimens showed no trace of a true syrinx, but exhibited a peculiar modification of the mesial septum in the pedicle-valve.

Prof. Garwood also spoke, and Dr. Vaughan briefly replied on behalf of the Authors.

14. Notes *on the* Culm *of* South Devon: Part I—Exeter District.

By Frederick George Collins, F.G.S. *With a* Report *on the* Plant-Remains, *by* E. A. Newell Arber, M.A., F.L.S., F.G.S.; *and* Notes *on* Carboniferous Cephalopoda *from the* Neighbourhood *of* Exeter, *by* George C. Crick, Assoc.R.S.M., F.G.S. (Read June 14th, 1911.)

[Plate XXXII—Map.]

Contents.

I. Introduction.

Some ten years ago, my friend Mr. C. Davies Sherborn pressed upon me the desirability of making a thorough examination of the Culm Measures of South Devon, and promised every assistance in his power if I would undertake the task. He pointed out that a great part of the area was practically unexplored, and, if systematically worked, might yield results that would fix exactly the position of the beds in the Carboniferous System.

The sequel has shown the soundness of his judgment. But, living on the spot, I knew well the reputation of the beds. To quote some recent writers, Mr. E. A. Newell Arber says:—

> 'From a palæobotanical standpoint the Culm Measures offer a most unpromising field .....; it is nowadays a matter of the greatest difficulty to obtain specimens sufficiently wel. preserved to admit of satisfactory determination.'[1]

Principal A. W. Clayden writes:—

> 'They [the Exeter type of Culm Measures] are singularly devoid of recognizable fossils.'[2]

Occasional essays of my own at collecting had but confirmed me in a similar opinion. However, I at length undertook a more systematic search for fossils than appears to have hitherto been made. Since then my schoolboy son Oliver and I have spent much of our leisure in patiently searching the Culm rocks of the neighbourhood, and the examination of a definite line of country having now been completed, the time has arrived to publish the results thus far obtained.

---

[1] Phil. Trans. Roy. Soc. ser. B, vol. cxcvii (1905) p. 294.

[2] 'The History of Devonshire Scenery' 1906, p. 53.

II. Literature.

The city of Exeter stands almost at the eastern extremity of the southern outcrop of the Culm Measures, and therefore it is not surprising that the earlier literature, which naturally is concerned with broad and general views of the formation as a whole, contains scarcely a reference to the beds under consideration. Had fossils been found in any number, doubtless the district would have compelled attention as time went on; but the order of succession has been fought out mainly elsewhere.

In the Geological Survey Memoir on 'The Geology of the Country around Exeter' 1902, the Culm Measures are classified lithologically by Mr. Ussher, and the only fossils recorded are *Posidonomya becheri* and two goniatites called *Glyphioceras sphæricum* and *Gl. crenistria* (pp. 9 & 15).

Dr. Wheelton Hind, in vol. ii of his monograph of the Carboniferous Lamellibranchiata (Pal. Soc. 1901–1905, p. 174) and in Proc. Geol. Assoc. vol. xxi (1910) p. 463, speaks as if the age of the Devon Culm were well-known. But it is clear that he really refers to the age of the North Devon beds, because he only mentions the Waddon-Barton area of the south. The fossils from Waddon Barton were long since described; and, so far as I and my advisers are aware, no collections of fossils have ever been made and no lists have yet been published for the southern Culm area of Devon. It is also clear from Mr. Ussher's memoir (1902) that no material from this southern area, beyond the three fossils which he records, was available to the Survey officers when the memoir was published.

III. Previous Records of Fossils.

The earliest mention that I have found of Culm fossils from this neighbourhood is contained in Phillips's 'Figures & Descriptions of the Palæozoic Fossils of Cornwall, Devon, & West Somerset' 1841. In the preface to that work (p. vii) the author says

> 'and lately Mr. Drury of Exeter has favoured me with the sight of some of the goniatites which have been found near that place.'

These would appear to have been all of one species, as it is only of *Goniatites inconstans* that the locality is quoted as 'near Exeter (Mr. Drury's cabinet).'[1]

In 1842 R. A. C. Austen [Godwin-Austen] mentions *Goniatites mixolobus* and *G. crenistria*, and also the following plants: *Pecopteris lonchitica*, *Neuropteris heterophylla*, *Sphenopteris latifolia* or *acutifolia*, *Cyclopteris* sp., and *Calamites*, as occurring in South-East Devon,[2] but he gives no further particulars of locality.

---

[1] J. Phillips, 'Figures & Descriptions of the Palæozoic Fossils of Cornwall, Devon, & West Somerset' 1841, pp. vii, 123–24 & pl. li, fig. 238.

[2] 'On the Geology of the South-East of Devonshire' Trans. Geol. Soc. ser. 2, vol. vi, pt. 2 (1842) pp. 461–62.

Dr. Thomas Shapter, writing in 1842 ('Climate of South Devon' p. 173), says:—

> 'This formation contains many vegetable impressions, of which the chief are *Cyperites bicarinata*, *Pecopteris lonchitica*, the knots, apparently, of a *Sigillaria*, and a great variety of *Calamites*, as well as *Goniatites*, and other marine fossils. These usually occur in somewhat flattened concretionary nodules, which are found both in the soft and hard beds, and in many cases seem to have constituted nuclei, around which the oxide of iron, alumina, iron pyrites, and other minerals of which they are composed, have collected. The neighbourhood of Pinhoe, near Exeter, has been very productive in these fossils; they have also been discovered in the same range of hills on the south-eastern side of the Exe, near Oakford Bridge on the Creedy, at Cleeve, near Newton St. Cyres, and near the Okehampton road, about 5 miles from Exeter.'

In the second edition, published twenty years later, the following paragraph (p. 79) is added to the foregoing:—

> 'In the upper beds of this series, at Pinhoe and Cleeve, casts of the beautiful *Goniatites inconstans* occasionally occur with numerous little fossils about the size of a large shot, which have been regarded (Parfitt) as the eggs of a marine animal.' [Probably young goniatites.]

In the Royal Albert Memorial Museum at Exeter there are a few Culm fossils, presented many years ago by the Devon & Exeter Institution. Those of them which came from the neighbourhood of Exeter have been named by Mr. Crick, and comprise:—

(1) A solid goniatite found in a pebble [nodule?] near Cowley Bridge, Exeter. J. T. Underhill.
    Glyphioceras phillipsi Foord & Crick.

(2) A solid goniatite, No. 6834, locality unrecorded.
    Glyphioceras inconstans (J. Phillips).

(3) Eight small goniatites, No. 4541, labelled 'Exeter. J. T. Underhill.'
    Dimorphoceras (*? discrepans* Brown sp.).
    Glyphioceras striolatum (J. Phillips).

(4) Two goniatites labelled 'Dunsford Road, above Pocombe Bridge, Exeter. J. T. Underhill.'
    Glyphioceras reticulatum (J. Phillips).
    Glyphioceras striolatum (J. Phillips).

The collection of the late W. Vicary contains some specimens of goniatites, which are thus mentioned in the Survey Memoir:—

> 'Reference has been made to evidences of close connection amounting to a passage from the shales and grits of the Exeter type downward into the Basement beds. In Mr. Vicary's collection, Goniatites labelled from three localities in which there are no signs of the occurrence of characteristic Basement beds point to this. The localities are Cocktree Moor, near North Tawton, on the southern border of the New Red Valley of Crediton in Sheet 324; near Pinhoe Church in raddled shales and grits; in the cliff by Bonhay Road, Exeter. The writer visited Pinhoe and the Bonhay Road section recently, but beyond occasional plant-traces his search was unrewarded by the discovery of fossils.'[1]

The Champernowne Collection, recently acquired by the authorities of the British Museum, contained no Culm fossils from this district.

---

[1] W. A. E. Ussher, 'The Geology of the Country around Exeter' Mem. Geol. Surv. 1902, p. 16.

IV. LIST OF FOSSILS AND LOCALITIES (see Map, Pl. XXXII).

It will be seen from the foregoing pages that fossil records are not numerous. This is the less remarkable when we remember that what Mr. Ussher terms the 'Exeter type' of Culm rock is unsuitable for building or road-metalling, and that consequently quarries are few and far between. In the absence of both quarries and coast-sections, the fossil-hunter has to rely, as we soon found, upon hedge- and stream-sections and the surfaces of ploughed fields. But, while perfect specimens are indeed rare, fossils are abundant in many localities, and frequently have their characteristic ornament beautifully preserved. The plants, however, are so fragmentary that, as Mr. Arber states, it is often difficult or impossible to determine species.

It was decided to begin the search on the south-west and north-east line running through the city of Exeter, along which the Culm rocks disappear beneath the New Red Series. Subsequently, the work was extended at each end of the line: on the south-west to the confines of Dartmoor, and on the north-east to include the Culm inlier of Spray Down—making a total distance of about 17 miles. As the strike is generally east and west, it was hoped that we should be working in successive horizons, although, in consequence of the manifold contortions of the beds, this was by no means certain.

Mention will also be made in the notes of Waddon Barton. That place is not properly included in this paper, but belongs to the one to follow, wherein I hope to work along a line from north to south.

I have been fortunate in securing the kind assistance of Mr. E. A. Newell Arber, who has named the plant-remains, and of Mr. G. C. Crick, who has named the cephalopoda and whose notes are appended to this paper. The lamellibranchiata and gasteropoda have not yet been named.

Besides determining the series of fossils obtained by me, Mr. Crick has carefully examined the material in the Vicary Collection in the British Museum, and also the few fossils from these beds preserved in the Exeter Museum, and thus has allowed me to incorporate in this short communication everything that is at present available for study.

The localities are numbered on the accompanying Map (Pl. XXXII) from south-west to north-east.

(1) Canonteign. (Road-cutting.)

Small brachiopoda.
Posidonomya becheri Bronn (one specimen showing the wrinkled periostracum).
Glyphioceras sp.
Phillipsia cliffordi H. Woodward.

(2) Popehouse[1] Close (surface of a ploughed field on Court Barton Farm Christow).

Pleurodictyum (?) or *Michelinia (?)*.
Posidonomya becheri Bronn.
Glyphioceras crenistria? (J. Phill.).
Glyphioceras spirale (J. Phill.).
Orthoceras sp.?
Phillipsia cliffordi H. Woodward.

(3) Christendown Clump, near Doddiscombsleigh.

Cherts containing radiolaria of very large size. First found by Mr. C. Davies Sherborn.[2]

(4) Down Lane, Doddiscombsleigh. (Hedge-section.)

Seminula ambigua? (J. de C. Sow.).
Posidonomya becheri Bronn.
Glyphioceras, probably the adult stage of *Gl. reticulatum*.
Stroboceras sulcatum (J. de C. Sow.), fragment.

[All the fossils from this locality were kindly named for me by Dr. Wheelton Hind, F.R.C.S., in February 1907.]

(5) Woodah, Doddiscombsleigh.

Small brachiopod.
Posidonomya becheri Bronn. Recorded by Mr. W. A. E. Ussher.[3]
Glyphioceras spirale (J. Phillips).
Phillipsia cliffordi (?) H. Woodward.

(6) Willhayes Copse. (Hedge-section half a mile west of Dunchideock.)

Glyphioceras sp.
? Young of *Glyphioceras reticulatum* (J. Phill.).

(7) Bottom of Idestone Hill, and bottom of Ashlake Road.

Glyphioceras beyrichianum (de Kon.) var.?
Glyphioceras reticulatum? (J. Phill.).
Glyphioceras striolatum (J. Phill.).
Mariopteris (?) sp.

(8) Perridge Tunnel.

Encrinite stems.
Glyphioceras crenistria [recorded by Mr. Ussher (*op. cit.* p. 15)].
Glyphioceras cf. *reticulatum* (J. Phill.).
Orthoceras sp. (found by Mr. A. S. Horne).

(9) Perridge (Pateshill Copse).

Urnatopteris cf. *tenella* (Brongn.).
Neuropteris sp.
Alethopteris sp.
Sphenopteris obtusiloba (?) Brongn.

(10) Pocombe Road-cutting.

Glyphioceras reticulatum (J. Phill.).
Glyphioceras striolatum (J. Phill.).
Glyphioceras beyrichianum (de Kon.).

The first two specimens are in the Exeter Museum.

(11) Lane near Barley House, Exeter (opposite the entrance to a field in which a landslip occurred, 1904).

Glyphioceras striolatum? (J. Phill.).

(12) Bonhay Road, Exeter.

Dimorphoceras (*? discrepans* T. Brown).
Glyphioceras (probably *striolatum* J. Phill.).
Glyphioceras crenistria (J. Phill.).
Glyphioceras sphæricum (W. Martin).

The two last-named specimens form part of the Vicary Bequest to the British Museum.

---

[1] Misprinted 'Gopehouse' in the map, Pl. XXXII.

[2] Proc. Zool. Soc. 1908 (2) p. 433.

[3] 'The Geology of the Country around Exeter' Mem. Geol. Surv. 1902, p. 9.

(13) Stoke Road (roadside section below Stoke Wood).

Glyphioceras reticulatum (J. Phill.).
Glyphioceras inconstans (J. Phill.).

(14) Mincing Lake. (Stream-section.)

Glyphioceras reticulatum (J. Phill.).
Glyphioceras (probably *striolatum* J. Phill.).
Glyphioceras davisi Foord & Crick.
Small lamellibranchiata.

My friend Mr. Lewis James found an impression of *Glyphioceras* in a hedge-section a short distance north of Mincing-Lake Bridge.

(15) Chaingate Lane, Pinhoe.

Neuropteris sp.
Urnatopteris cf. *tenella* (Brongn.).

(16) Messrs. Saunders's Brickfield, Pinhoe.

Pterinopecten papyraceus (J. Sow.).
Euomphalus sp.
Small gasteropods.
Dimorphoceras (? discrepans T. Brown).
Glyphioceras reticulatum (J. Phill.).
Glyphioceras davisi Foord & Crick.
Glyphioceras beyrichianum (de Kon.), var. *crenatum* Haug.
Glyphioceras beyrichianum (de Kon.), var. *biplex* Haug.
Glyphioceras phillipsi Foord & Crick.
Glyphioceras striolatum (J. Phill.).
Orthoceras koninckianum d'Orbigny.
Orthoceras obtusum T. Brown.
Orthoceras sp. *a*.

(17) North of Westwood Church. (Hedge-section.)

Odontopteris (?) sp.
Neuropteris schlehani Stur.
Neuropteris (Cyclopteris) sp.
Neuropteris sp.

(18) Clyst Hydon. (Hedge-section.)

Neuropteris schlehani (?) Stur.
Neuropteris cf. *heterophylla* Brongn.
Mariopteris (?) sp.
Sphenopteris sp.
Alethopteris sp.
Calamites (?) sp.
Lepidodendron, part of a leaf-base.
Bothrodendron (?) sp.
Trigonocarpus (?) sp.
Sigillaria sp. (decorticated).
Stigmaria sp.

V. Report on the Plant-Remains.

Mr. Arber's report on the plant-remains is as follows:—

'8th March, 1910.

'I have now completed an examination of the specimens which you sent last week. The collection is very typical of the best possible specimens that one can get from the Culm Measures. I fully understand that this collection represents much hard work, and I am quite certain from the evidence in North-West Devon that, imperfect and fragmentary as they are, your specimens represent as good examples as it will ever be possible to get from these beds. At the same time they are so fragmentary that it is almost impossible to determine them. A *Neuropteris*, or possibly two, appear to be common, and in one case the species appears to be clearly *N. schlehani*, Stur, which I have already described from Devon. Another fern-like plant may be *Urnatopteris tenella* (Brongn.), though one cannot be certain. Several *Calamites* occur, but I cannot determine the species. The small scars shown on certain specimens are very puzzling: I am inclined to regard them as isolated root-scars of *Stigmaria.* If so, they show how much these plants were drifted and broken before incrustation took place. These fossils might also conceivably be small branch-scars of a *Calamite*, but I do not think this likely. These specimens are obviously of Upper Carboniferous age, but they are not sufficiently numerous to indicate the horizon..... I think that you have got better specimens than any hitherto obtained from the neighbourhood of Exeter..... Your specimens leave nothing to wish for in preservation, but they are too fragmentary to be determined.

'I remain, yours truly,
E. A. Newell Arber.,

In 1902 Mr. Arber[1] suggested that it would be well

> 'if possible, to drop the term Culm Measures altogether in speaking of the Devon Carboniferous rocks, and to apply the nomenclature adopted with regard to other British areas of similar age.'

I venture to hope that the present paper brings such a change one step nearer.

A series of the specimens referred to in this paper will be placed in the British and in the Exeter Museums.

My warmest thanks are due to Mr. Arber and to Mr. Crick, both of whom have spent much time and taken infinite trouble over my often fragmentary material. I am also indebted for kind assistance to Mr. J. Allen Howe, Dr. Hind, Mr. F. R. Rowley, Curator of the Exeter Museum; and to Mr. T. H. Withers, who kindly named the trilobites.

To Mr. W. P. Studholme I am indebted for kind permission to work at Fordlands, and to Messrs. Saunders for allowing me to collect at the Pinhoe Brickfields. Last, but not least, I must thank Mr. C. Davies Sherborn, who has been with me over the ground described in this paper, and who not only suggested the work but has helped me at every turn.

VI. NOTES *on* CARBONIFEROUS CEPHALOPODA *from the* NEIGHBOURHOOD *of* EXETER.[2] By GEORGE C. CRICK, Assoc.R.S.M., F.G.S.

The following notes refer chiefly to specimens which have been collected by Mr. F. G. Collins. A few of the fossils examined are in the Exeter Museum, while some, which formed part of the Vicary Bequest, are in the British Museum. The specimens generally are not well preserved, and the Ammonoids but rarely exhibit the suture-lines.[3]

DIMORPHOCERAS (? DISCREPANS Brown, sp.).

1849. *Goniatites discrepans* T. Brown, 'Illustrations of the Fossil Conchology of Great Britain & Ireland' p. 28 & pl. xxi, figs. 8 & 15.[4]

The genus *Dimorphoceras* appears to be represented by a much compressed, poorly-preserved, imperfect specimen, about 10 mm. in diameter, exposed on the surface of a piece of a nodule from Pinhoe. About half of the outer whorl seems to have belonged to the body-chamber; the rest of the outer whorl is septate, and near the umbilicus exhibits portions of several septa, but these are too incomplete for the definite determination of the species. The fossil is possibly referable to *Dimorphoceras discrepans* (Brown).

Two specimens in the Exeter Museum, labelled 'Exeter' and

---

[1] 'The Fossil Flora of the Culm Measures of North-West Devon, &c.' Phil. Trans. Roy. Soc. ser. B, vol. cxcvii (1905) p. 320.

[2] Communicated by permission of the Trustees of the British Museum.

[3] In the following notes a record of the complete distribution of each species is not attempted.

[4] For references and synonymy, see A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 222.

numbered 4541, seem to belong to this species; they are associated with several examples of what appears to be *Glyphioceras striolatum*.

The species has been recorded from the Vale of Todmorden, High Green Wood, and Hebden Bridge (Yorkshire),[1] as well as from the marine bands in the Coal Measures of Lancashire.[2]

Localities.—Pinhoe brickfield[3]; and 'Exeter [Exeter Mus.].'

GLYPHIOCERAS BEYRICHIANUM (de Koninck).

1843. *Goniatites beyrichianus* L. G. de Koninck in J. J. d'Omalius d'Halloy, 'Précis élémentaire de Géologie' p. 515.
1897. *Glyphioceras diadema* (H. E. Beyrich); A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 202 (in part).
1898. *Glyphioceras beyrichianum* (L. G. de Koninck); E. Haug, 'Études sur les Goniatites' Mém. Soc. Géol. France, Paléont. vol. vii, no. 18, p. 95 & pl. i, figs. 1–21, 23.

The species usually recorded from England under the name of *Glyphioceras diadema* includes, according to Prof. Haug, *Gl. beyrichianum* (L. G. de Koninck) with several varieties, and *Gl. striolatum* (J. Phillips).[4]

Var. *biplex* Haug.—Pinhoe brickfield has yielded several examples of this variety, with diameters ranging from about 5·5 mm. to 21 mm., the umbilicus of the largest being about 10 mm. wide. This variety is also represented doubtfully from the 'bottom of Idestone Hill.'

Var. *crenatum* Haug.—Some small, widely-umbilicated, internal casts from Pinhoe, having a diameter of about 5 mm., closely resemble this variety of Prof. Haug, but their umbilical margins are smooth. They may be widely-umbilicated young examples of *Glyphioceras striolatum*.

Var. *coronatum* Haug.—This variety may be represented by a poor example from Pocombe.

Glyphioceras diadema has been recorded from the Pendleside Series, and indicated as passing up into the Millstone Grits and Lower Coal-Measures.[5] It has also been recorded from the Lower Coal-Measures of Lancashire,[6] and from South Wales.[7]

Localities.—Var. *biplex*: Pinhoe brickfield, and possibly also from the 'bottom of Idestone Hill'; var. *crenatum*: probably from Pinhoe brickfield; var. *coronatum*: possibly from Pocombe.

---

[1] A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897), pp. 222–23. Dr. A. S. Woodward has told the present writer that the specimens C 5293, there recorded as from 'Halifax,' were really from Hebden Bridge.

[2] W. Hind, Q. J. G. S. vol. lxi (1905) p. 544.

[3] Unless otherwise stated, the specimens are at present in the collection of Mr. F. G. Collins.

[4] J. Phillips, 'Geol. Yorks.' pt. 2 (1836) p. 234 & pl. xix, figs. 14–19.

[5] W. Hind & J. A. Howe, Q. J. G. S. vol. lvii (1901) App. B, table facing p. 402.

[6] H. Bolton, Trans. Manchester Geol. Soc. vol. xxviii (1904–1905) p. 413.

[7] W. Hind, Geol. Mag. dec. 5, vol. i (1904) p. 585.

GLYPHIOCERAS STRIOLATUM (J. Phillips).

1836. *Goniatites striolatus* J. Phillips, 'Geol. Yorks.' pt. 2, p. 234 & pl. xix, figs. 14–19.
1897. *Glyphioceras diadema* (H. E. Beyrich); A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3, p. 202 (in part), with fig. 98.
1898. *Glyphioceras striolatum* (J. Phillips); E. Haug, 'Études sur les Goniatites' Mém. Soc. Géol. France, Paléont. vol. vii, no. 18, p. 92 & pl. i, figs. 22, 24–27.

This appears to be the most commonly occurring species at Pinhoe. To it are referred numerous examples, usually ranging in diameter up to 12 or 13 mm., while some display the fine sculpture exceedingly well. A nodule from this locality contains a specimen, about 19 mm. in diameter, possessing the fine sculpture of the species enclosed within another whorl, which is crushed and apparently quite smooth, having a diameter of a little more than 40 mm. Another nodule from the same locality exhibits a similar example, also showing the finely-sculptured inner whorl at a diameter of about 20 mm. surrounded by a portion of the crushed outer whorl of rather more than 40 mm. in diameter; the ornaments exhibit a prominent crest on the outer portion of the lateral area and a deep sinus on the periphery; the umbilicus appears to have been relatively small, infundibuliform, and with a rounded margin. Another example in the British Museum from Pinhoe [C 9122 *a*], 8 mm. in diameter, is referred to this species.

A crushed example and counterpart, labelled as from 'near Barley (opposite entrance to field in which landslip occurred),' seems to be referable to this species. Its transverse striæ are but slightly waved, not so much as in *Glyphioceras reticulatum*.

An imperfect impression from the 'bottom of Ashlake Road' probably belongs to this species, and possibly also a specimen from the 'bottom of Idestone Hill.' It is also doubtfully represented at Mincing Lake.

The impression of a portion of a whorl about 35 mm. high, in a piece of black shale from Perridge Tunnel, displays a sculpture similar to that of the large outer whorls already mentioned from Pinhoe. Transverse ornaments are very conspicuous, but there are no traces of any longitudinal lines; near the peripheral margin of the lateral area the shell possessed a distinct groove as in *Gl. bilingue*, but the shell-ornaments do not agree with those of that species, and resemble quite closely the sculpture of the large examples from Chokier (Belgium), figured as *Glyphioceras diadema* by Foord & Crick,[1] and subsequently referred by Prof. Haug (*op. supra cit.* pp. 92 & 94) to *Gl. striolatum* (J. Phillips).

Several small specimens in the Exeter Museum, labelled 'Exeter' [No. 4541], appear to belong to this species; also an example, 10 mm. in diameter, in the same Museum, labelled 'Dunsford Road, above Pocombe Bridge.'

Phillips's *striolatus* has been regarded as a synonym of Beyrich's

---

[1] *Op. cit.* figs. 98 *a* & 98 *b*, p. 203.

diadema,[1] but Prof. Haug considers these species distinct, and for the latter adopts L. G. de Koninck's name *beyrichianum*.[2]

The localities given by Phillips [3] for this species are :—'In shale, Kulkeagh; near Enniskillen; in shale, High-Green Wood, near Todmorden.'

Localities.—Pinhoe brickfield, near Exeter [F. G. C. & Brit. Mus.]; near Barley; Exeter [Exeter Mus.]; Dunsford Road, above Pocombe Bridge [Exeter Mus.]; probably from the 'bottom of Ashlake Road,' Mincing Lake, and Perridge Tunnel; possibly also from the 'bottom of Idestone Hill'; and Bonhay Road.

GLYPHIOCERAS RETICULATUM (J. Phillips).

1836. *Goniatites reticulatus* J. Phillips, 'Geol. Yorks.' pt. 2, p. 235 & pl. xix, figs. 26–32; *G. gibsoni* J. Phillips, *ibid.* p. 236 & pl. xx, figs. 13–18.
1897. *Glyphioceras reticulatum* A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3, p. 193 (with references & synonyms).[4]
1898. *Glyphioceras reticulatum* E. Haug, 'Études sur les Goniatites' Mém. Soc. Géol. France, Paléont. vol. vii, no. 18, p. 87 & pl. i, figs. 32–39, 41, 42.

The specimens from Pinhoe here referred to this species are relatively thicker than the Yorkshire forms. A well-preserved and apparently uncrushed example, 31 mm. in diameter, is 17 mm. thick, and has an umbilicus about 8·3 mm. wide at its margin, while the height of the outer whorl is about 14 mm. Portions of the test are beautifully preserved, and show both the prominent transverse and some very faint longitudinal striæ. The *jugosum*-stage of the species is also represented. The British Museum collection contains several fairly well-preserved examples from the Vicary collection, labelled 'Pinhoe.'[5]

The best-preserved of these [C 9118] is elliptical, its diameters being 35 and 24 mm. respectively. Its constrictions are less curved than is usual in *Gl. reticulatum*, and in this respect the fossil approximates to *Gl. excavatum*[6]; but the type-specimen of that species—a specimen with the whole of the outer whorl non-septate and apparently belonging to the body-chamber—is a more compressed shell than ordinary examples of *Gl. reticulatum*. Moreover, if one of the specimens, a completely septate example 20 mm. in diameter in the Gilbertson Collection, is correctly identified as *Gl. excavatum*, the lateral lobe of the suture-line of that species is, as described by Phillips, more acute than in *Gl. reticulatum*;

---

[1] A. H. Foord & G. C. Crick, *op. cit.* p. 202.

[2] E. Haug, *op. cit.* pp. 92 & 95. See also *ante*, p. 400.

[3] 'Geol. Yorks.' pt. 2 (1836) p. 234.

[4] See also A. H. Foord, 'Monograph of the Carboniferous Cephalopoda of Ireland' (Pal. Soc.) pt. 5 (1903) p. 182.

[5] Nos. C 9115–18, C 12662 (young), & C 12800. Probably these are the fossils mentioned by Mr. W. A. E. Ussher, 'Geology of the Country around Exeter' Mem. Geol. Surv. 1902, p. 16.

[6] *Goniatites excavatus* J. Phillips, 'Geol. Yorks.' pt. 2 (1836) p. 235 & pl. xix, figs. 33–35. Not *Goniatites excavatus* J. Phillips, 'Palæoz. Foss. Cornwall, Devon, & W. Somerset' 1841, p. 121 & pl. l, fig. 232 = *Mæneceras molarium* (G. F. Whidborne).

but unfortunately the suture-lines are not visible in the specimens from Devon. An examination of a number of examples of the two species leads me to endorse Phillips's statement that the two species are closely allied, if not the same.

With this species is identified a well-preserved example, 19 mm. in diameter, in the Exeter Museum, labelled 'Dunsford Road, above Pocombe Bridge.'

Imperfect impressions of shells and quite young specimens from the 'bottom of Ashlake Road' and a young shell from Willhayes Copse probably belong to this species, which we have also recognized from 'Mincing Lake.'

The British Museum collection includes from the Vicary Bequest two examples from Newton St. Cyres, 4 miles north of Exeter, that belong to this species. They are 18·5 and 13·5 mm. in diameter respectively, the smaller one having a still smaller example (4 mm. in diameter) attached to it.

To this species is also referred an example from 'under Stoke Wood,' measuring rather more than 20 mm. in diameter, exhibiting the sculpture of the test. Embedded in the same piece of matrix is a specimen apparently referable to *Glyphioceras inconstans*.

Dr. Hind records the species from Doddiscombleigh (South Devon),[1] and states that

> 'this species occurs at certain horizons in the Pendleside Series, in practically every locality in the Midlands where these beds occur.'

He also records it from the marine band beneath the Gin-Mine Coal at Nettlebank (North Staffordshire).[2] It has moreover been recorded from the Lower Coal-Measures of Lancashire[3] and from South Wales.[4]

Localities.—Pinhoe brickfield, near Exeter [F. G. C. & Brit. Mus.]; Dunsford Road, above Pocombe Bridge; bottom of Ashlake Road; Mincing Lake; Newton St. Cyres [Brit. Mus.]; 'under Stoke Wood'; and Willhayes Copse.

GLYPHIOCERAS DAVISI Foord & Crick.

1897. *Glyphioceras davisi* A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3, p. 198, figs. 95 *a*–95 *c*.

1898. *Glyphioceras reticulatum*, var. *davisi* E. Haug, 'Études sur les Goniatites' Mém. Soc. Géol. France, Paléont. vol. vii, no. 18, p. 90.

This species is represented from Mincing Lake by a portion of the outer whorl, with the included part of the penultimate whorl of a rather large example. The inner whorls are wanting.

The portion of the penultimate whorl consists of about a third of a volution, is sublanceolate in cross-section, being at its mid-length about 24 mm. high and 21 mm. thick at its prominent rounded umbilical margin. The outer third of the whorl is pinched

---

[1] 'The Naturalist' 1909, p. 170.

[2] Q. J. G. S. vol. lxi (1905) p. 538.

[3] H. Bolton, Trans. Manchester Geol. Soc. vol. xxviii (1904) p. 413.

[4] A. Strahan, &c. 'The Geology of the South Wales Coalfield, pt. viii—The Country around Swansea' Mem. Geol. Surv. 1907, p. 25.

together, producing a strong rounded ridge along the middle of the lateral area. There are traces of the suture-lines.

The fragment of the outer whorl comprises about an eighth of a volution, increasing near the umbilical margin to nearly a quarter of a volution. It is sublanceolate in cross-section, 48 mm. high, and about 38 mm. wide at the umbilical margin. It shows the faint strongly-curved growth-lines and the prominent umbilical margin of the species, but the ridge on the middle of the lateral area is here almost obsolete. Since this portion reveals no traces of the suture-lines, it seems to have formed part of the body-chamber.

This imperfect example indicates a fossil larger than the type-specimen, for in the latter with a diameter of 60 mm. the outer whorl was only 27 mm. high.

Prof. Haug (*loc. supra cit.*) regards the species as either a senile form or a variety of *Glyphioceras reticulatum.*

The type-specimen was obtained from the late James W. Davis, of Halifax, and is recorded as being from that locality; but Dr. Smith Woodward told the present writer that the collection of fossils of which it formed a part really came from Hebden Bridge.

Dr. Hind & Mr. Howe record the species from the Pendleside Series of the Midlands, and indicate that it passes upwards into the Grits and the Lower Coal-Measures.[1]

Locality.—Mincing Lake.[2]

GLYPHIOCERAS INCONSTANS (J. Phillips).

1841. *Goniatites inconstans* J. Phillips, 'Palæoz. Foss. Cornwall, Devon, & West Somerset' p. 123 & pl. li, figs. 238 *a*–238 *e*.

A distorted example in the Exeter Museum [No. 6834], of which the locality is unrecorded, seems to be referable to this species, but the main ribs in passing from the edge of the umbilicus are more forwardly-inclined than they are represented to be in Phillips's figures; the ornaments form a distinct orad-concave curve on the periphery.

This species greatly resembles young forms of *Glyphioceras reticulatum*. a species to which it evidently is closely allied, for, according to Phillips, it passed through a series of forms parallel to those described by him in regard to *Gl. reticulatum*, with which species he at first believed it to be identical; but, compared with that species, he pointed out (*op. cit.* p. 124) that

> 'the umbilicus is here larger, the ridges on the inner edge of the whorls are continued into the cavity, and the back [periphery] is in all corresponding ages broader, and in the young state more cariniform in the middle.'

Embedded in a piece of shale from 'under Stoke Wood,' and containing a specimen here referred to *Gl. reticulatum*, there is

---

[1] Q. J. G. S. vol. lvii (1901) App. B, table facing p. 402.

[2] [Since the paper was read Mr. Collins has found in the Pinhoe brickfield a much better example of this species, showing the beautifully-ornamented test.—*G. C. C., August 5th, 1911.*]

a distorted specimen (now elliptical in outline), the diameters of which are 19 mm. and 12·5 mm. respectively, that seems to belong to this species.

The only locality given by Phillips (*loc. cit.*) for this species is 'near Exeter (Mr. Drury's cabinet),' and this is the sole species from the neighbourhood of Exeter mentioned by him.

Localities. — 'Under Stoke Wood'; locality unrecorded [Exeter Mus. No. 6834].

GLYPHIOCERAS PHILLIPSI Foord & Crick.

1836. *Goniatites obtusus* (pars) J. Phillips, 'Geol. Yorks.' pt. 2, p. 234 & pl. xix, fig. 12 (*non* figs. 10, 11 & 13 = *Glyphioceras obtusum*).

1897. *Glyphioceras phillipsi* A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3, p. 172.

Of the five examples from Pinhoe here referred to this species, two, from the collection of the late Mr. William Vicary, are in the British Museum Collection [C 9120 & C 9121]. These specimens, 43 mm. and 35 mm. in diameter respectively, exhibit the shell-ornament, and are entirely septate, so that the shell must have attained considerable dimensions. The type measures 32 mm. in diameter, but a completely septate example in the British Museum collection [C 5300] from Hebden Bridge is 36 mm. in diameter.

Of the examples in Mr. Collins's collection, one, displayed in counterpart in a broken nodule, is 23 mm. in diameter, and exhibits a considerable portion of the test, but no traces of the suture-lines; the others are portions of crushed internal casts, entirely devoid of the test, but exhibit the character of the sculpture, indicating shells which measured at least 33 and 60 mm. in diameter respectively.

A well-preserved example in the Exeter Museum, 12·6 mm. in diameter and exhibiting the ornaments of the test, is also referred to this species. It is labelled 'Stoke Road, Exeter, just beyond Cowley Bridge (in pebble).'

The locality of the type-specimen is unrecorded, but the species was identified by its authors from High-Green Wood and Hebden Bridge.[1] It has also been recorded from the Pendleside Series of the following localities:—Coldcoates[2]; Crimsworth Dean, Horsebridge Clough, near Todmorden[3]; and at Foynes Island (Co. Limerick)[2]; also from the marine band beneath the Gin-Mine Coal at Nettlebank (North Staffordshire).[2] Dr. Hind states that it has never been found in the Carboniferous Limestone Series.[2]

Localities.—Pinhoe brickfield, near Exeter [F. G. C. & Brit. Mus.]; Stoke Road, Exeter, just beyond Cowley Bridge (in pebble) [Exeter Mus.].

---

[1] Dr. Smith Woodward tells me that the collection which included the specimens, recorded in the original description of the species as from Halifax, really came from Hebden Bridge. They were obtained from the late James W. Davis, of Halifax.

[2] W. Hind, Q. J. G. S. vol. lxi (1905) p. 538.

[3] W. Hind & J. A. Howe, *ibid.* vol. lvii (1901) App. B, table facing p. 402.

GLYPHIOCERAS SPHÆRICUM (Martin).

1809. *Conchyliolithus Nautilites sphæricus* W. Martin, 'Petrifacta Derbiensia' p. 15 & pl. vii, figs. 3–5.

1814. *Ammonites sphæricus* J. Sowerby, 'Min. Conch.' vol. i, p. 116 & pl. liii, fig. 2 [B.M. No. 43871].[1]

A fairly well-preserved pyritized specimen in the British Museum, obtained with the Vicary Bequest and labelled 'Bonhay Road, Exeter,' is referred to this species. Its measurements are:—diameter, 18·4 mm.; greatest thickness, 15 mm.; height of outer whorl, 7 mm.; ditto above preceding whorl, 4 mm.; width of umbilicus, 4 mm. The suture-line is well shown, and agrees with that of the specimen figured by Sowerby, which may also have been Martin's type. This is probably one of the specimens mentioned by Mr. Ussher as being in the Vicary collection.[2]

In a 'decomposed blackish ferruginous rock' exposed in the valley between Five-Mile Hill Cross and Ball Oaks, between Tedborn St. Mary, Whitestone, and Holcombe Burnell, Mr. Ussher records the occurrence of badly-preserved goniatites, 'suggesting the presence of *Glyphioceras sphæricum*.'[3] Dr. Hind records the species from the 'black shales and limestones' at Venn, in North Devon; and notes[4] its presence in South Devon in the cherty representatives of the Codden-Hill or *Prolecanites-compressus* Beds. It has also been recorded in a pyritized condition from Fremington (North Devon).[5]

In the Midlands, Dr. Hind & Mr. Howe have identified the species from the Carboniferous Limestone of Castleton (Derbyshire), Park Hill, Cracoe, and Thorpe (Yorkshire), and Clitheroe (Lancashire)[6]; while the same authors and Mr. G. W. Lamplugh[7] have recorded the species from the Poolvash Limestone (Isle of Man).

Locality.—Bonhay Road, Exeter [Brit. Mus. C 9111].

GLYPHIOCERAS CRENISTRIA (J. Phillips).

1836. *Goniatites crenistria* J. Phillips, 'Geol. Yorks.' pt. 2, p. 234 & pl. xix figs. 7–9.[8]

From Popehouse Close, Christow, there is an uncrushed specimen, consisting of about half a shell, 22 mm. in diameter, 14 mm. thick, with an umbilicus some 4 mm. wide at its margin; it is ornamented with fine crenulated striæ, which are direct on the lateral area and form only an exceedingly shallow orad-concave curve on

---

[1] For references and synonymy, see A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 157; also A. H. Foord, 'Monogr. Carb. Cephal. Ireland' (Pal. Soc.) pt. 5 (1903) p. 154.

[2] 'Geology of the Country around Exeter' Mem. Geol. Surv. 1902, p. 16.

[3] *Ibid.* p. 9.

[4] 'The Naturalist' 1909, pp. 169, 170.

[5] Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 160.

[6] Q. J. G. S. vol. lvii (1901) App. A, table facing p. 402.

[7] 'Geology of the Isle of Man' Mem. Geol. Surv. 1903, p. 262.

[8] For references and synonymy, see A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 160; and A. H. Foord, 'Monogr. Carb. Cephal. Ireland' (Pal. Soc.) pt. 5 (1903) p. 157.

the periphery; it exhibits a single faint constriction, but no suture-lines, and therefore apparently formed part of the body-chamber. It is doubtfully referred to this species.

From Bonhay Road, Exeter, and forming part of the Vicary Bequest, the British Museum collection includes a somewhat distorted pyritized internal cast, 28 mm. in diameter, 17·5 mm. thick, with an umbilicus 3·5 mm. wide, having the septal sutures and shell-ornament characteristic of this species.

The locality of the type-specimen is 'Bolland,' the other localities for the species given by its author being Queen's County, Fermanagh, and the Isle of Man. Phillips[1] subsequently recorded the species from Swimbridge and Venn in North Devon, and from Trescot in South Devon. Dr. Wheelton Hind also records it from the black shales and limestones at Venn.[2]

Mr. Ussher[3] records the occurrence of this species in a 'dark-grey hard mudstone' at Perridge Tunnel, but the only example submitted to the writer from this locality does not exhibit the characteristic sculpture of the species. It is here referred to *Glyphioceras striolatum*.

Dr. W. Hind & Mr. J. A. Howe record this species from the Carboniferous Limestone of Yorkshire and Derbyshire[4]; while from the Poolvash Limestone (Isle of Man) the species has been recorded both by the same authors and by Mr. G. W. Lamplugh.[5]

Localities.—Bonhay Road, Exeter [Brit. Mus. C 1908]; possibly also from Popehouse Close, Christow.

GLYPHIOCERAS SPIRALE (J. Phillips).

1841. *Goniatites spiralis* J. Phillips, 'Palæoz. Foss. Cornwall, Devon, & West Somerset' p. 121 & pl. l, fig. 233.[6]

This species is well represented from Waddon Barton, in the collections both of Mr. Collins and of the British Museum, by the ordinary crushed examples exhibiting the strong longitudinal ornaments and the periodical constrictions. Mr. Collins's collection also includes a beautifully-preserved example from Popehouse Close, Christow.

Besides Waddon Barton in South Devon, the species occurs at Bampton,[7] Hele[8] and Venn[9] in North Devon, being, as Mr. Ussher

---

[1] 'Palæoz. Foss. Cornwall, Devon, & West Somerset' 1841, pp. 121, 122.

[2] 'The Naturalist' 1909, p. 169.

[3] 'Geology of the Country around Exeter' Mem. Geol. Surv. 1902, p. 15.

[4] Q. J. G. S. vol. lvii (1901) App. A, table facing p. 402.

[5] 'Geology of the Isle of Man' Mem. Geol. Surv. 1903, p. 262.

[6] For references and synonymy see A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 210; and A. H. Foord, 'Monogr. Carb. Ceph. Ireland' (Pal. Soc.) pt. 5 (1903) p. 191.

[7] J. Phillips, 'Pal. Foss. Cornwall, Devon, & West Somerset' 1841, p. 121; A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 211; and W. A. E. Ussher, 'The Geology of the Quantock Hills, &c.' Mem. Geol. Surv. 1908, p. 35.

[8] A. H. Foord & G. C. Crick, *op. cit.* p. 211.

[9] W. Hind & J. A. Howe, Q. J. G. S. vol. lvii (1901) App. B, table facing p. 402; and W. Hind, 'The Naturalist' 1909, p. 169.

states (*op. cit.* p. 35),

> 'a common fossil in the upper beds of the Lower Culm (*Posidonomya* Beds) . . . both in the northern and southern outcrops.'

Dr. Hind & Mr. Howe record the species from the Pendleside Group at Pendle Hill[1]; it has also been recorded from Congleton Edge (Cheshire),[2] and from South Wales.[3]

Localities.—Waddon Barton[4] [F. G. C. & Brit. Mus.]; Popehouse Close, Christow; Woodah.

? NOMISMOCERAS SPIRORBIS (J. Phillips).

1836. *Goniatites spirorbis* J. Phillips, 'Geol. Yorks.' pt. 2, p. 237 & pl. xx, figs. 51–55.
1841. *Goniatites spirorbis* J. Phillips, 'Palæoz. Foss. Cornwall, Devon, & West Somerset' p. 122 & pl. li, fig. 236.[5]

This species appears to be represented by an impression on the surface of a small slab, labelled 'Waddon Barton,' which does not exhibit any example of *Glyphioceras spirale*, the form most commonly occurring at this locality. Phillips's type-specimen came from Black Hall, Bolland,[6] and he recorded the species also from Westleigh in North Devon.[7] Dr. Hind & Mr. Howe record the species from the Pendleside Group at Black Hall, Bolland, and from near Todmorden; also from the Venn and Swimbridge Culm Shales of North Devon.[8] It has been recorded from Codden Hill, near Barnstaple,[9] and doubtfully from Waddon Barton,[10] near Chudleigh (South Devon).

Locality.—Waddon Barton,[11] near Chudleigh (South Devon).

PROLECANITES (?) sp.

The British Museum collection contains from Pinhoe the impression (in part of a nodule) of one side of a slowly-increasing shell, elliptical in outline, its diameters being about 45 and 30 mm. respectively, the corresponding measurements of the umbilicus being 25 and 15 mm. respectively. The whorls seem to have been rather compressed, the margin of the periphery subangular, the umbilicus wide and its walls step-shaped, the umbilical zone of the whorl fairly well defined, relatively narrow and convex. The test appears to have been ornamented with extremely faint striæ; these

---

[1] *Op. supra cit.* vol. lvii (1901) App. B, table facing p. 402.

[2] W. Gibson & W. Hind, Q. J. G. S. vol. lv (1899) p. 554.

[3] A. Strahan, &c. 'The Geology of the South Wales Coalfield, pt. viii—The Country around Swansea' Mem. Geol. Surv. 1907, p. 25.

[4] This locality is not properly included in the present paper.

[5] For references and synonymy see A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 213.

[6] 'Geol. Yorks.' *loc. cit.*

[7] 'Palæoz. Foss. &c.' p. 123.

[8] Q. J. G. S. vol. lvii (1901) App. B, table facing p. 402.

[9] *Ibid.* vol. li (1895) p. 653.

[10] A. H. Foord & G. C. Crick, Catal. Foss. Ceph. Brit. Mus. pt. 3 (1897) p. 215.

[11] This locality is not properly included in the present paper.

are sigmoidal and forwardly-directed on the lateral area, making a feeble orad-concave curve on the inner portion and a feeble orad-convex curve on the outer part of the whorl, and are suddenly deflected backwards at the peripheral margin where the test is raised into obscure folds. The form of the shell and the nature of its ornaments suggest the genus *Prolecanites*; but, as there are no traces of the septa, its reference to this genus is somewhat doubtful.

Locality.—Pinhoe brickfield, near Exeter.

ORTHOCERAS KONINCKIANUM d'Orbigny.

1844. *Orthoceras anceps* L. G. de Koninck, 'Descr. des Anim. Foss. Terr. Carb. Belg.' p. 517 & pl. xlv, figs. 7 *a*–7 *b* (*non* Münster).
1850. *Orthoceratites koninckianus* d'Orbigny, 'Prod. de Paléont.' vol. i, p. 113.
1888. *Orthoceras koninckianum* d'Orbigny; A. H. Foord, Catal. Foss. Ceph. Brit. Mus. pt. i, p. 119.

This species is represented by an example from Pinhoe, almost completely embedded in a portion of a nodule, which also contains besides other fossils an example of the species referred to in these notes as *Glyphioceras striolatum*. Only a length of about 10 mm. of the shell is visible, but this is sufficient to show a couple of its characteristically-shaped annulations and the fine transverse raised lines of the test. The specimen is subcircular in transverse section, its diameters being 20 and 18 mm. respectively.

The British Museum collection contains an example from Hebden Bridge (Yorkshire) [C 5272]. Through the kindness of Dr. Wheelton Hind, the writer has also had an opportunity of examining a small block from Foynes Island (County Limerick) containing an example of this species associated with adult and immature forms of both *Glyphioceras reticulatum* and *Gl. striolatum*, as well as a *Dimorphoceras* (probably *discrepans* Brown), and innumerable small calyciform goniatites exhibiting the protoconch. In fact, this assemblage reminds one very much of the assemblage occurring in the nodules from Pinhoe. According to Dr. Wheelton Hind,[1] these beds at Foynes Island contain a fauna characteristic of the Pendleside Series. Dr. Hind & Mr. Howe[2] record this species from the Pendleside Group at Crimsworth Dean, Horsebridge Clough, near Todmorden (Yorkshire).

Locality.—Pinhoe brickfield, near Exeter.

ORTHOCERAS OBTUSUM T. Brown.

1841. *Orthocera obtusa* T. Brown, Trans. Manchester Geol. Soc. vol. i (1841) p. 219 & pl. vii, fig. 36.

One of the most interesting cephalopods from Pinhoe is an example of this species, consisting like the type-specimen (with a cast of which I have compared it) of the posterior portion of the body-chamber, the posterior surface being apparently an impression of the anterior surface of the last septum. The specimen is

---

[1] 'Monogr. Brit. Carb. Lamell.' (Pal. Soc.) vol. ii, pt. 3 (1904) p. 173.
[2] Q. J. G. S. vol. lvii (1901) App. B, table facing p. 402.

conoidal and depressed, 49 mm. long, with an elliptical cross-section, of which the diameters at the anterior end measure 35 and 25 mm. respectively. The siphuncle, seen at the posterior end of the specimen, is at about a third of the shorter diameter from the surface. The fossil tapers rather rapidly, the sides being apparently continuous with the basal surface. The test is rather thick, ornamented with slightly waved, somewhat irregular, upwardly-imbricating lines, which are very close together (three or four in the space of 1 mm.) on the posterior part of the specimen, their distance apart gradually increasing to about 1·5 mm. on the anterior part of the fossil.

The type-specimen came from High-Green Wood, near Hebden Bridge (Yorkshire), and is preserved in the Manchester Museum. Through the kindness of Dr. Wheelton Hind, the writer has had an opportunity of examining a very similar specimen from the Pendleside Series of Hebden Bridge. Mr. Bolton records it from the Lower Coal-Measures of Lancashire.[1]

Locality.—Pinhoe brickfield, near Exeter.

ORTHOCERAS sp. *α*.

A small fragment from the Pinhoe brickfield seems to belong to this genus. It is exposed in counterpart on the split surfaces of part of a nodule, on one surface being displayed the internal cast of the shell, and on the other the inner side of the test; but the boundaries of the shell are not shown. The shell is slightly curved, and ornamented with regular transverse, rounded, equidistant ridges. The fragment, which is 21 mm. long and about 13 mm. wide at its widest part, bears fourteen ridges, the two last, probably the hindermost, being much narrower than the rest. Although the surface of the test cannot be seen, judging from its internal aspect the ridges appear to have been rounded and neither forwardly-imbricating as in *Orthoceras obtusum*, which occurs at the same place, nor so fine as the ornamentation of the specimen from Pope house Close, near Christow, mentioned below.

Locality.—Pinhoe brickfield, near Exeter.

ORTHOCERAS sp. *β*.

Another species is represented by a flattened fragment, preserved in counterpart on the split surfaces of a small slab from Popehouse Close, near Christow. The fossil is about 28 mm. long, 15 mm. and 11·5 mm. wide at the anterior and posterior ends respectively, and ornamented with very fine, transverse, raised lines, which are much finer than those of the example from Pinhoe, five of them occupying a space of 2 mm.

Locality.—Popehouse Close, near Christow.

---

[1] Trans. Manchester Geol. Soc. vol. xxviii, pt. 14 (1904) p. 413.

The cephalopoda, therefore, identified from the Carboniferous rocks in the neighbourhood of Exeter, are:—

AMMONOIDEA.

Dimorphoceras (? discrepans).
Glyphioceras beyrichianum.
Gl. crenistria.
Gl. davisi.
Gl. inconstans.
Gl. phillipsi.
Gl. reticulatum.
Gl. sphæricum.
Glyphioceras spirale.
Gl. striolatum.
? Nomismoceras spirorbis.
Prolecanites (?) sp.

NAUTILOIDEA.

Orthoceras koninckianum.
O. obtusum.
O. sp. *a* and *O.* sp. *β*.

From the 'Pendleside Group' Dr. Hind & Mr. Howe[1] record the following cephalopoda:—

AMMONOIDEA.

Dimorphoceras gilbertsoni.
D. looneyi.
Gastrioceras carbonarium.
G. listeri.
Glyphioceras bilingue.
Gl. davisi.
Gl. diadema.
Gl. implicatum.
Gl. nitidum.
Gl. phillipsi.
Gl. reticulatum.
Gl. spirale.
Gl. stenolobum.
Glyphioceras vesica.
Nomismoceras spirorbis.
Prolecanites compressus.
Pr. serpentinus.

NAUTILOIDEA.

Ephippioceras clitellarium.
Orthoceras aciculare.
O. koninckianum.
O. steinhaueri.
O. sulcatum.
Temnocheilus carbonarius.
T. concavus.

and from the underlying Carboniferous Limestone[2]:—

AMMONOIDEA.

Glyphioceras crenistria.
Gl. mutabile.
Gl. sphæricum.
Gl. striatum.
Gl. truncatum.
Nomismoceras rotiforme.
N. vittigerum.
Prolecanites compressus.
Pronorites cyclolobus.

NAUTILOIDEA.

Actinoceras breynii.
A. giganteum.
Cœlonautilus subsulcatus.
Discites discus.
D. planotergatus.
D. sulcatus.
Phacoceras oxystomus.
Solenocheilus cyclostoma.
S. dorsalis.
Stroboceras bisulcatum.
Temnocheilus coronatus.
Thrinoceras hyatti.

Comparing the list of South Devon forms with that of the fauna of the 'Pendleside Series' and that of the Carboniferous Limestone as tabulated above, we cannot fail to be impressed with the great resemblance of this fauna to that of the 'Pendleside Series,' a resemblance which is emphasized by the occurrence of such forms as *Glyphioceras reticulatum*, *Gl. davisi*, *Gl. beyrichianum*, and *Gl. striolatum* (the two last-named having been usually recorded as

---

[1] Q. J. G. S. vol. lvii (1901) App. B, table facing p. 402.
[2] *Ibid.* App. A, table facing p. 402.

Gl. diadema), *Orthoceras koninckianum* and *O. obtusum*[1]; though it should be mentioned that all these forms, excepting *O. koninckianum*, have been recorded either as occurring in the Lower Coal-Measures or as passing up into the grits and Lower Coal-Measures.

The two forms which seem to indicate a somewhat lower horizon than the 'Pendleside Group' are *Glyphioceras crenistria* and *Gl. sphæricum*, species characterizing the Carboniferous Limestone. These, as already said, are stated to have been found at Bonhay Road (Vicary), and it is to observed that their mode of preservation differs from that of the rest of the fossils in that they are pyritized, more or less uncompressed, and exhibit the suture-lines.

Respecting the 'Pendleside Series,' which in the Midlands is stated to consist of about 1000 feet of black shales, resting on the top of the massif of Carboniferous Limestone, Dr. Hind states that[2]

> 'The Pendleside Series thins out rapidly to the south of Derbyshire, and is only represented by a few feet in Leicestershire and Shropshire. Still further south, I consider that the Bishopton Beds in South Wales and the Lower Culm Series of Devonshire are the homotaxial equivalents of the Pendleside Series of the Midlands. The lithological similarity of the series in Devonshire, and especially the peculiar fauna of the Lower Culm, agree so markedly with the characters of the Pendleside Series that one cannot be blind to the evidence. Moreover, the Lower Culm is overlaid by grit beds, which are in turn overlaid by soft shales with bullions at Instow containing:—
>
> *Pterinopecten papyraceus.*
> *Posidoniella lævis.*
> *Gastrioceras listeri.*
> *Gastrioceras carbonarium.*
> *Dimorphoceras gilbertsoni.*
> *Orthoceras* sp.
>
> a fauna which is abundant in the Lower Coal-Measures of Lancashire and the Midlands; and at Robert's Quarry, near Bideford, immediately above beds containing a fairly rich and typical Coal-Measure flora, is a band of fawn-coloured, iron-stained shale with *Carbonicola acuta*, a characteristic shell of the middle portion of the Coal-Measures, so that one may safely infer that the Culm-Measures of Devonshire represent the Carboniferous sequence of the Midlands, *minus* the massif of Carboniferous Limestone.'

During the visit of the Geologists' Association to North Devon at Easter 1910, Dr. Wheelton Hind gave a lecture on the correlation of the Carboniferous rocks in North Devon with those in other areas. The report[3] of the lecture states that the species which Dr. Hind regards as the most important zonal forms, and, taken together, form the faunal sequence which characterizes the lower part of the Upper Carboniferous rocks, are:—

Zone of	*Gastrioceras listeri*[4]	Millstone Grit.
,,	*Glyphioceras bilingue*[4]	Millstone Grit.
,,	*Glyphioceras spirale* and *Gl. diadema*	Pendleside Series.
,,	*Glyphioceras reticulatum (maximum)*	
,,	*Nomismoceras rotiforme* and *Posidonomya becheri*	

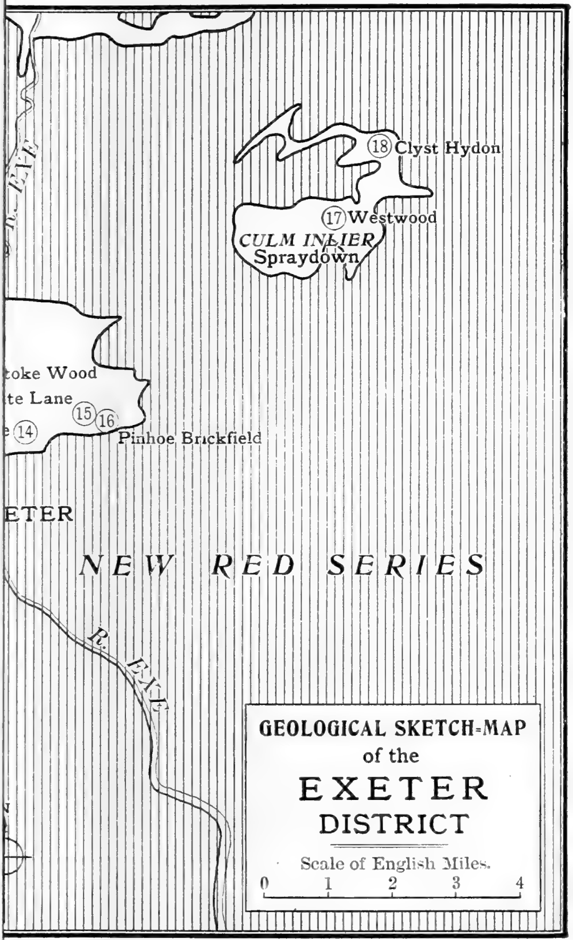
---

[1] This species is not recorded by Dr. Wheelton Hind from the 'Pendleside Series'; but the type-specimen (see *antea*, p. 410) came from High-Green Wood, near Hebden Bridge, and we have also seen the species from the 'Pendleside Series' of Hebden Bridge.

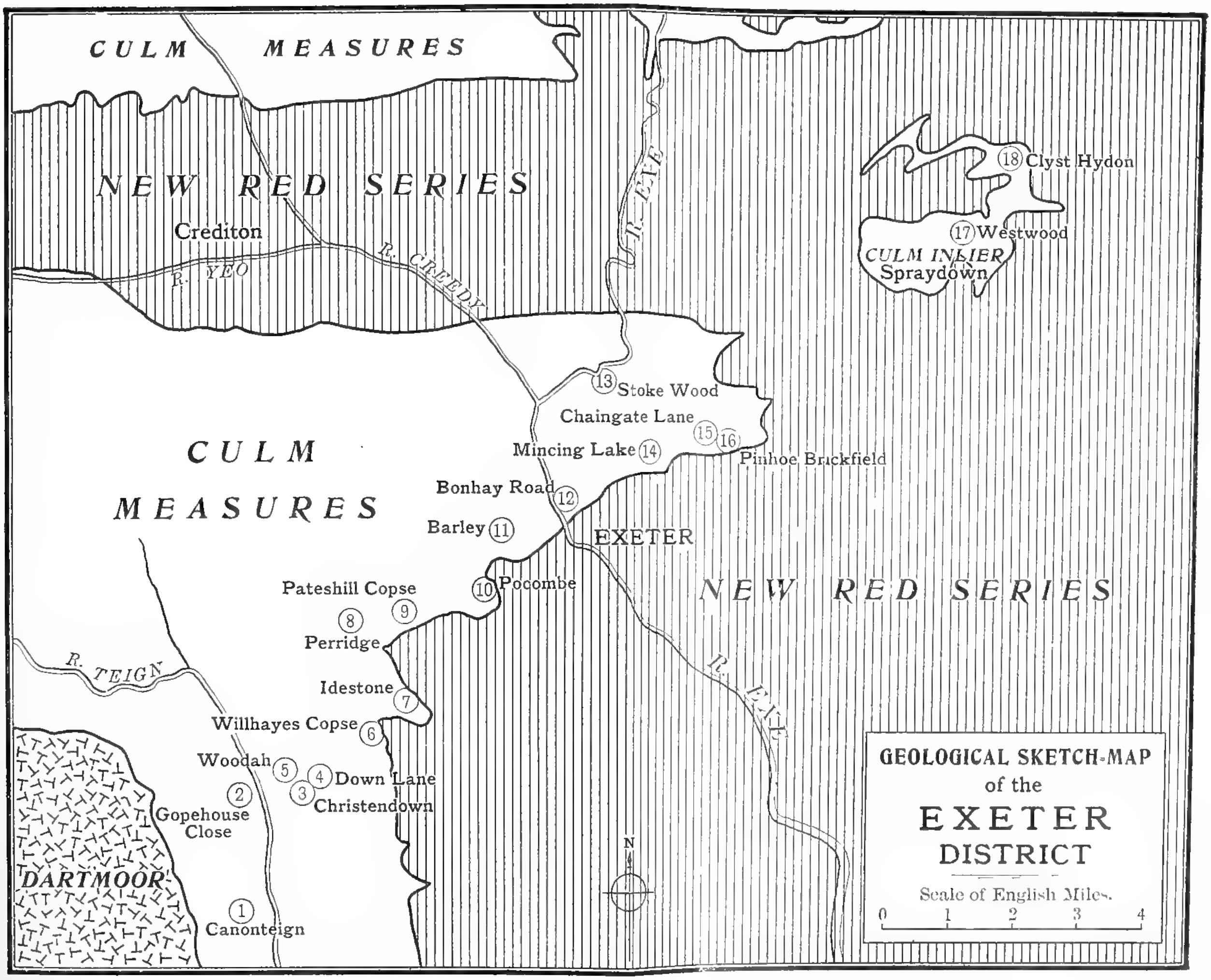
[2] 'Monogr. Brit. Carb. Lamell.' (Pal. Soc.) vol. ii, pt. 3 (1904) p. 174.

[3] Proc. Geol. Assoc. vol. xxi (1910) pp. 463–64.

[4] By the list given above (p. 411) it will be seen that both these forms were included by Dr. Hind & Mr. Howe in the fauna of the 'Pendleside Group.'



Neighbourhood of Exeter.



Geological Sketch-Map of the Neighbourhood of Exeter.

These are underlain by the *Prolecanites-compressus* Beds of the *Cyathaxonia* Zone, with which Dr. Hind correlates the Codden-Hill cherts. The report goes on to say:—

> 'These beds [Codden-Hill cherts] are succeeded by black shales and limestones with *Posidonomya becheri* and some compressed goniatites. *Glyphioceras reticulatum* has been obtained by Mr. Inkermann Rogers, and Mr. Hamling notes the presence of *Gl. spirale* at Filleigh. The latter species is very plentiful in South Devon, at Waddon Barton. Most of the other fossils have been found in the south part of the Culm area.
>
> 'At Instow occur beds characterized by *Gastrioceras listeri*, which are succeeded by a series containing typical Coal-Measure plants and *Carbonicola acuta*.'

It concludes with the statement:—

> 'So in the difficult, much-disturbed county of Devon, all the life-zones of the Pendleside Series known in the Midlands, with the exception of *Glyphioceras bilingue*, have been found.'

The last sentence is not quite clear, because, according to Dr. Hind & Mr. Howe, the 'Pendleside Series' occurs between the Carboniferous Limestone Series and the Millstone Grit, and in the list of zones above cited the 'zone of *Glyphioceras bilingue*' is referred to the Millstone Grit.

Again, in the second paragraph above quoted, after referring to the plentiful occurrence of *Gl. spirale* at Waddon Barton in South Devon, the report states: 'Most of the other fossils have been found in the south part of the Culm area.' It is not clear to which fossils allusion is here made, and reference to the literature containing such records is not given.

The fossils, however, described in the present note, support for South Devon what Dr. Hind has stated to be the case in North Devon, namely, that the Lower Culm-Measures are the homotaxial equivalents of the 'Pendleside Series' of the Midlands.[1]

EXPLANATION OF PLATE XXXII.

Geological sketch-map of the neighbourhood of Exeter, on the scale of 3 miles to the inch. [*For* 'Gopehouse Close' *read* 'Popehouse Close.']

DISCUSSION.

Dr. T. F. SIBLY noticed that while the plant-remains collected in this area were referred by Mr. Newell Arber to the Upper Carboniferous, the molluscan fauna definitely indicated, on the other hand, a Lower Carboniferous horizon, namely, the Pendleside Series, underlying the level of the 'plant-break' in the Midland succession. He asked the Author whether the mollusca and the plants had been found in different localities.

Mr. DEWEY remarked that, at Codden Hill and elsewhere in North Devon, *Prolecanites compressus* occurred in beds of radiolarian chert, which were overlain at Venn and Swimbridge by shales and lime-

---

[1] It may be mentioned that quite recently the 'Pendleside Series' has been discussed by Dr. Balduin Nebe in his work on the Culm fauna of Hagen in Westphalia (Neues Jahrb. Beilage-Bd. xxxi, pt. 2, 1911, pp. 487 *et seqq.*).

stones containing *Posidonomya becheri* and other fossils constituting the fauna of the Pendleside Series. But in North Cornwall and the area west and east of Dartmoor, an apparently different order of deposition was found among the beds. Along the coast near Boscastle the Upper Devonian slates underlay carbonaceous shales, and these were succeeded by grits with occasional flows of lava, while the radiolarian cherts were not met with for a distance of some 3 miles farther north, and then 90 feet of them formed the headland known as Firebeacon Point. Eastwards, this order was continued as far as Dartmoor, and near Launceston limestones were seen dipping beneath radiolarian cherts. These limestones contain *Posidonomya becheri*; but no fossils had been found in the cherts. It was, however, difficult to believe that the massive cherts which formed a nearly continuous outcrop for 20 miles were not on the same horizon as the beds at Codden Hill. If this were so, the position of the Codden-Hill Beds with regard to the limestone beds in North Cornwall differed from their position in North Devon.

But it must be remembered that overthrusting had reversed the normal succession over wide areas in North Cornwall. At Tintagel this had affected the Upper Devonian sequence, while at Holne on the Dart, south-east of Dartmoor, the Upper Devonian was thrust upon the Culm beds. It did not, therefore, seem improbable that overthrusting might have brought about the apparent difference in the succession in North Cornwall.

The AUTHOR, in reply to Dr. Sibly, said that the bulk of the plants sent to Mr. Arber came from the north of the area, but broken plant-remains occurred throughout the series.

15. *The* LLANDOVERY *and* ASSOCIATED ROCKS *of* NORTH-EASTERN MONTGOMERYSHIRE.[1] By ARTHUR WADE, B.Sc., F.G.S. (Read April 26th, 1911.)

[PLATES XXXIII–XXXVI.]

CONTENTS.

I. INTRODUCTION.

THE district investigated is one which was well loved by Murchison, who paid many visits, about the year 1836, to Powis Castle while preparing his great work on the 'Silurian System.'

It extends for a distance of over 7 miles in a north-easterly direction from a point a mile or so south of Welshpool in Montgomeryshire, and includes a tract of country embracing the Vale of Guilsfield, and a portion of the valley of the Severn. It is bounded on the west by the watershed of the Vyrnwy, the area covering nearly 40 square miles. The country may be broadly described as consisting of three parallel ridges of Silurian rocks running in a north-north-easterly direction, with two wide intervening valleys containing subsidiary though usually more precipitous ridges, formed by the escarpments of rocks of Ordovician age. It was among these fertile valleys and finely wooded hills that De Quincey found solace during part of his early wanderings.

II. HISTORICAL REVIEW.

Murchison, in 1839, was the first to give any account of the structure of this region. Speaking of the whole of the country between the Breiddens and the Berwyns, he describes [1][2] the Silurian strata as lying

> 'in undulations or troughs .... constituting a number of parallel anticlinal and synclinal lines.' (Ch. xxiv, pp. 300 *et seqq.*)

---

[1] Thesis approved for the Degree of Doctor in Science in the University of London.

[2] Numerals in square brackets refer to the Bibliography (§ III) on p. 418.

Of the particular district with which I now propose to deal he has much to say. He describes very fully the Welshpool Dyke, and notes its apparent effect upon the strike of the neighbouring rocks, which is generally north-north-east and south-south-west, the direction of the axis of the dyke. One very interesting passage is worthy of quotation: referring to the ridges in the Upper Park of Powis Castle, he says (*op. cit.* p. 290):—

> 'The dislocation in the higher ridge of the Upper Park changes its direction to east-north-east and west-south-west, according with that of the Breidden Hills, and it is therefore possible that the dyke of Welshpool and the lines of disturbance immediately proceeding from it, are only slight aberrations from a line of eruption of which the Breiddens was the chief focus; it is, however, to be observed that the disturbed line of Welshpool is parallel to the strike of the volcanic ridges of Corndon, whilst the Breidden Hills.... cut through the stratified deposits in a direction which diverges 45° from those parallels.'

In dealing with the stratigraphical succession of the area, he recognizes two divisions only:—

(1) An Upper Silurian division, consisting chiefly of dull grey shales containing occasional spherical concretions which he compares with the septaria of the London Clay. Owing to the absence of limestone-bands, he makes no attempt to differentiate between the Wenlock and the Ludlow.

(2) A Lower Silurian division, which he calls Caradoc Sandstone and Llandeilo Flags. It consists of impure sandy limestones in the upper beds, with conglomerates, hard grits, and mottled red-and-grey shales beneath. He describes sections at Powis Castle, Moel-y-garth, and the Gaerfawr, the first of which he illustrates by means of a diagram. With regard to the latter section he says (*op. cit.* p. 306):—

> 'This red conglomerate, overlying the whole system of the grey sandstones of the Gaerfawr, proves that the similar red conglomerate and gritty beds of Welshpool, Powis Castle, the Quakers' Burial Ground, and other places which rise from beneath the overlying mudstones or Upper Silurian rocks, form the upper strata of the Caradoc Sandstone or Lower Silurian rocks.'

It is now possible to differentiate between the Wenlock and the Ludlow; and it can also be shown that, instead of forming the upper strata of the Caradoc Sandstone, the Red Conglomerate Series lies unconformably upon them. It is, therefore, necessary to remove a part of the Conglomerate and associated beds from Murchison's Lower Silurian, and to establish a Llandovery group in the area.

In 1850 a geological map of the district, executed by W. T. Aveline & H. W. Bristow, with A. C. Ramsay as Local Director, was published by the Geological Survey, together with a section. For purposes of mapping, Murchison's grouping of the rocks was adopted. Wide areas are mapped as Wenlock Shale, which in reality are occupied by Ludlow Beds. The dividing-line between Upper and Lower Silurian is drawn at the base of the upper shale-beds, so that part of the Llandovery is mapped along with the Wenlock, while the lower portion is mapped with the Upper Ordovician strata.

In 1866, 'The Geology of North Wales' was published by the

Geological Survey. In it, Sir Andrew Ramsay mentions the disturbed state of the Wenlock Shales in this area, and notes the absence of the grit-beds at the base. With regard to the apparent conformity between the Upper and the Lower Silurian strata in Montgomeryshire, he says that

> 'it doubtless arises from the circumstance that during the deposition of the Upper Silurian rocks, the lower strata of this particular area had been but slightly disturbed.' [3] p. 207.

It will be seen later that this unconformity is greater than he anticipated. In the appendix on the fossils, J. W. Salter noted many specimens from the neighbourhood, as did also Robert Etheridge, in the enlarged edition published in 1881.

No further work appears to have been done in this district, until J. Bickerton Morgan began his investigations somewhere about the year 1884. In 1890, an abstract of his results was published [5]. He recognized the true age of the Red Conglomerate beds, and stated that they transgress upon 'different zones of the underlying Ordovician rocks.' The overlying shales, sandstones, and mudstones, he considered to be of Lower Wenlock age.

About the same time, he wrote two papers dealing with the geology of this part of Montgomeryshire, for the 'Montgomeryshire Collections' [6]. Here, he gave a somewhat fuller account of the different beds occurring in the district, and stated that the Bala Limestone with associated phosphatic beds occurs in Gwern-y-brain. A short list of fossils was also given, to prove the age of the Red Conglomerate beds. His conclusions were, in the main, correct, although some of the shales, considered by him to be of Wenlock age, must be regarded as belonging to the Upper Llandovery.

Morgan stated his intention to map the base of the Silurian in the area, but his labours were unfortunately cut short by his death.

In connexion with Morgan's work the late Prof. T. Rupert Jones [8], in 1890, dealt with the Ostracoda from the black shales of Gwern-y-brain. He described several new species, and showed the close affinity of these fossils with North American types.

In the years 1885 and 1890, Prof. Watts [4] & [7] dealt with the petrology and geology of the Breiddens and the Long Mountain. In the latter paper, he detailed a sequence with graptolite zones from the top of the Bala Beds to the Upper Ludlow. He noted the fact that the Llandovery grits and limestones lie unconformably upon the lower beds, and described a dyke of diabase thrust up along the junction at Cefn, near Buttington.

Further work on the petrology of the neighbourhood was done by Mr. Jevons [11] in 1904. He opined that certain of the 'diabases' described by Prof. Watts in the Breidden area are keratophyres.

In a further paper in 1905, Prof. Watts [12], after determining the age of these rocks to be probably post-Llandovery, welcomed the suggestion that they may be keratophyres, since it would bring about a tendency to unify the type of Ordovician and post-Ordovician intrusive rocks of different areas.

The work done by Miss Elles and Miss Wood [9] & [10] in 1900 in the Wenlock and Ludlow beds of the neighbouring Long Mountain district is now classical.

III. STRATIGRAPHICAL LITERATURE.

[1] 1839. Sir Roderick I. Murchison, 'The Silurian System' Chaps. xxiii & xxiv.

[2] 1854. Sir Roderick I. Murchison, 'Siluria' 1st ed.; 1872, 5th ed.

[3] 1866. Sir Andrew C. Ramsay, 'The Geology of North Wales' 1st ed., Mem. Geol. Surv. vol. iii; 1881, 2nd ed.

[4] 1885. W. W. Watts, 'On the Igneous & Associated Rocks of the Breidden Hills in East Montgomeryshire & West Shropshire' Q. J. G. S. vol. xli, p. 532.

[5] 1890. J. Bickerton Morgan, 'On the Strata forming the Base of the Silurian in North-East Montgomeryshire' Rep. Brit. Assoc. (Leeds) p. 816.

[6] 1885 & 1891. J. Bickerton Morgan, 'Montgomeryshire Collections' vol. xviii, p. 149 & vol. xxv, p. 359.

[7] 1890. W. W. Watts, 'The Geology of the Long Mountain, on the Welsh Borders.' Rep. Brit. Assoc. (Leeds) p. 817.

[8] 1890. T. Rupert Jones, 'On some Palæozoic Ostracoda from North America, Wales, & Ireland' Q. J. G. S. vol. xlvi, p. 1.

[9] 1900. Miss G. L. Elles, 'The Zonal Classification of the Wenlock Shales of the Welsh Borderland' Q. J. G. S. vol. lvi, p. 370.

[10] 1900. Miss E. M. R. Wood [Mrs. Shakespear], 'The Lower Ludlow Formation & its Graptolite Fauna' Q. J. G. S. vol. lvi, p. 415.

[11] 1904. H. S. Jevons, 'Note on the Keratophyres of the Breidden & Berwyn Hills' Geol. Mag. dec. 5, vol. i, p. 13.

[12] 1905. W. W. Watts, 'On the Igneous Rocks of the Welsh Border' Proc. Geol. Assoc. vol. xix, p. 173.

IV. THE STRATIGRAPHICAL SUCCESSION.

Before dealing in detail with the stratigraphical succession, I think it well to tabulate the full sequence obtained as a result of my investigations over the whole area. This is owing to the fact that a complete sequence cannot be established by any single section, in consequence partly of the overlapping of certain of the higher series, and partly (in all probability) of the thinning-out of beds in the area. The district is one of transition, and in many of its characters constitutes a connecting-link between neighbouring areas on every side. This feature has made it necessary to distinguish between a western facies and an eastern facies in certain cases.

The different group-names have been chosen to indicate places where the beds are best exposed and, as a rule, most fossiliferous.

Salopian.	Ludlow. 800 feet +	Yr Allt Group.	3. Sandy flags and shales, sometimes calcareous. 2. Hard thick flags, with thin shale-bands and septarian nodules. 1. Thin muddy shales.
	Wenlock. 200 feet.	B. Western facies.	Blue flags, gritty, with calcareous 'concretions' or boulders.
		A. Eastern facies.	Blue flags, as a rule minutely false-bedded, with earthy mudstones and a thin limestone-bed.
Valentian. 700 feet.	Buttington Group (=Tarannon Shales). 300 feet.		Barren shales, green and purple.
	Upper Llandovery ?	B. Western facies (Cloddiau Group) 250 feet.	2. Thick calcareous flags and mudstones. 1. Blue shales.
		A. Eastern facies (Cefn Group) 50 feet.	Thick calcareous flags, with *Pentamerus* Limestone.
	Lower Llandovery.	Powis-Castle Group. 100 feet.	Red sandstones and conglomerates, with occasional developments of limestone.
Ashgillian ? 50 feet.	Gwern-y-brain Group.		Black shivery phosphatic shales, with a band of black crystalline limestone near the base (=*Staurocephalus* Limestone ?).
Caradocian. 1300 feet.	Gaerfawr Group. 1000 feet.		3. Hard calcareous mudstones and limestones (=Lower Bala Limestone) with coarse ashy felspathic bands; thin phosphatic ashy shales at the base. 2. Massive grits, with bastard limestones. 1. Flags and grits, with some shale-bands.
	Pwll-y-glo Group. 300 feet.		Shales and flags, with some grit-bands.
Glenkiln-Hartfell (=*Dicranograptus* Shales).	Trilobite-Dingle Group. 1000 feet ?		2. Nodular mudstones and grey shales. 1. Splintery grey shales.

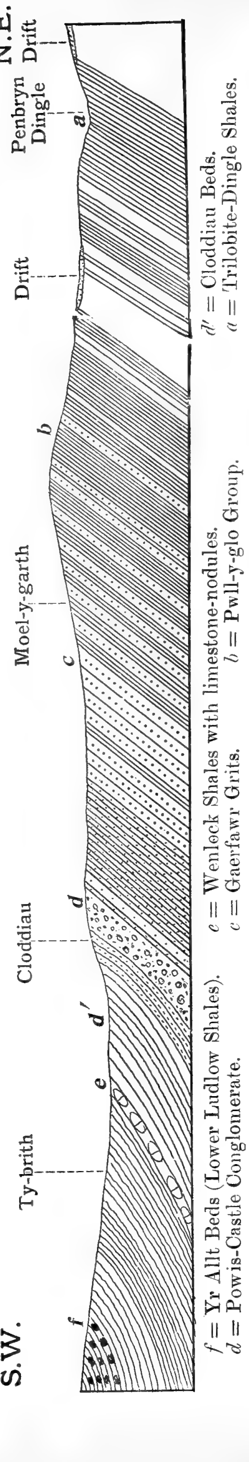


Fig. 1.—*Section from Penbryn Dingle to Trefnant Dingle, on the scale of 6 inches to the mile.*

Section across Moel-y-garth.
(Section I, fig. 1.)

The succession can be best established by a brief description of the two most typical sections in the area. A fairly complete succession may be obtained by starting at the foot of the dingle by Penbryn Farm and working in a south-westerly direction towards Cloddiau, Ty-brith, and Trefnant. It will afterwards be necessary to deal with each subdivision in detail.

Trilobite-Dingle Shales.—The stream by Penbryn Farm has cut a narrow gorge in a mass of dark-grey splintery shales. The weathered surfaces are usually stained reddish-brown or yellow. The upper beds near the road that crosses the top of the dingle consist of more massive mudstones, which present a nodular appearance when broken. About 800 feet of these beds are here exposed.

Pwll-y-glo Group.—As we pass along the road to the south-west, shales and mudstones soon give way to beds which differ, in that they are banded with flags as well as with occasional seams of grit. They can be traced in the road, and are exposed in an old quarry on the south side of it: about 300 feet of these strata are passed here. This group is intermediate in character between the underlying shales and the overlying grits.

Gaerfawr Group.—On our right we now face the fine tree-covered ridge of Moel-y-garth, which is an escarpment formed by the outcrop of hard massive grits. These grits are now seen crossing the road: they are in thick beds, with some shaly parting below and sandy flags above. Between 700 and 800 feet of these beds are passed over—the full sequence not being shown, owing to the overlapping of a massive red conglomerate.

Powis-Castle Group.—This conglomerate crosses the road about 150

yards from the tiny village of Cloddiau. There is no direct evidence here, either of overlap or of unconformity: these will become evident when we trace the group into other parts of the area mapped. Just east of the road the conglomerate is cut off sharply by a small fault, but it comes in again on the south. The conglomerate is followed by red sandstones and flags, which in turn give place to mudstones.

Cloddiau Group.—These beds, which are soft pale-grey mudstones, breaking readily with an uneven splintery fracture, are well seen on the right-hand side of the road, passing to the north-west through Cloddiau. They are over 200 feet thick.

Wenlock Shales.—As we pass along the stream towards Ty-brith Farm, a second gap in the succession is seen to occur; but immediately under the farm are blue flaggy beds of Wenlock age. Farther up the southern branch of the stream, the beds contain big limestone-boulders yielding Wenlock or Upper Llandovery fossils.

Yr Allt Group.—If we follow the branch which runs westwards in the direction of Trefnant, we see that the blue flaggy beds soon give place to a great series of thin buff-coloured shales, which become more sandy and flaggy as we proceed towards Trefnant Farm.

It will be observed that in this succession there are two gaps. The first is due to overlap by the Powis-Castle Conglomerate, and the other to drift in the stream-bed at Cloddiau. The latter gap can be filled in by examining the lane-section at Cloddiau; but the apparent conformity of the conglomerate to the beds below is misleading, and it will be necessary to consider briefly a second section.

Confirmatory Section in Gwern-y-brain.

(Section II, fig. 2, p. 422.)

Starting from Sarn Bridge, about half a mile to the north of Guilsfield, a road runs off to the left up a long narrow valley known as Gwern-y-brain, which cuts through the Gaerfawr ridge.

Trilobite-Dingle Shales.—These beds are not well exposed in Gwern-y-brain, being obscured by drift. Their relation to the overlying rocks is, however, well shown in the next dingle to the north by Middle House.

Pwll-y-glo Group.—The peculiar splintery shales and flags of the group are readily recognized in the first exposure in this dingle. Their thickness corresponds pretty closely with that observed in the Moel-y-garth section.

Gaerfawr Grits.—A great series of massive grits with shaly partings towards the base is now exposed. In places these beds are

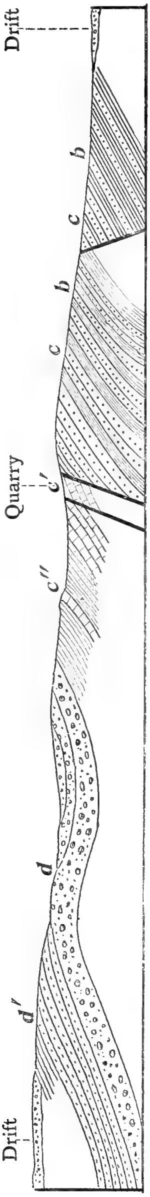


Fig. 2.—*Section exposed in Gwern-y-brain, on the scale of 6 inches to the mile.*

d' = Cloddiau Beds.
c' = Bala Limestone.
d = Powis-Castle Conglomerate.
c = Gaerfawr Grits.
c'' = Gwern-y-brain Shales, with limestone-band.
b = Pwll-y-glo Group.

richly fossiliferous, and are bastard limestones similar in all respects to those of the Caradoc Grits of Hoar Edge. These become more calcareous towards the top, where they are well exposed in two quarries which are now being worked. Here they are fossiliferous blue-grey beds—impure limestones—containing coarse gritty bands which consist largely of fragments of volcanic origin. Several small strike-faults are present in the neighbourhood of the quarries. The whole of the sequence is here not less than 1000 feet thick.

Gwern-y-brain Group.—Above the quarries, a series of jet-black beds cross the stream. A hard bed, forming a little waterfall, proves to be a band of black crystalline limestone about 10 feet thick. Above this comes 50 feet of black shivery shales.

Powis-Castle Group.—The Red Conglomerates and Sandstones cover these beds. Their apparent thickness is misleading, owing to a series of small rolls.

The Cloddiau Group of mudstones follows, and these are covered by shales of Wenlock age, but the succession is here obscured by drift.

V. DETAILED DESCRIPTION OF THE SUBDIVISIONS.

(A) Ordovician Rocks.

(1) Trilobite-Dingle Shales.—These beds are the lowest exposed in the district around Welshpool. They are best seen in a small dingle west of the town, called by Murchison Trilobite Dingle. At the southern end of the dingle, purple and grey shales are seen dipping almost due west. These beds are very fine-grained and well-bedded, and frequently show the presence of slickensides and incipient strain-slip cleavage. Occasionally the beds are nodular, and pass into bluish micaceous and flaggy mudstones. The joints are usually stained red and orange with iron-oxide. The beds are much disturbed, owing to the proximity of the Welshpool Dyke on the west.

At the head of the dingle, the beds are stained red, and the dip repeatedly changes; finally, they pass under the Red Conglomerate of Cherry-tree Bank.

On the western side of the dingle, the shales abut against the conglomerate which forms the wall of the Welshpool Dyke. The character of the junction indicates that the shales are cut off on the west by a fault which throws down the Powis-Castle Conglomerate and the Welshpool Dyke itself. Towards the east, the beds again end abruptly against buff-coloured shales which yield Lower Ludlow graptolites. The junction is best seen at the southern end of the dingle behind the old Military Depôt. Here, evidently, is a great fault with a downthrow to the east of apparently over 1000 feet. This fault may be called the Bron-y-Buckley Fault, from the fact that the wood in which Trilobite Dingle is situated is known by this name. On the south, shales occur under the Red Conglomerate of Powis-Castle Park, which are probably the southern extension of an inlier of Trilobite-Dingle Beds.

On the north, similar beds occur in the ditches by Cefn-sych Farm, in the dingle below Sale Farm and in Trelydan Dingle. They strike north-north-eastwards, and are folded into a series of small anticlines. The strata are jointed at right angles to the strike, the joint-planes dipping 65° to 70° south-eastwards. Towards the top of the section in Trelydan Dingle the shales dip in opposite directions on opposite sides of the stream: on one side up stream, on the other down stream. This is due to one of a series of faults which cross the stream here.

Under Trelydan Cottage a great fault throws down a small anticline of Silurian beds, including a limestone-band which contains fossils of Wenlock age. This fault is the northern continuation of the Bron-y-Buckley Fault. Farther north, the beds are hidden under deposits of drift and alluvium. In this area the shales do not contain the abundance of *Trinucleus concentricus* which characterizes those of Trilobite Dingle; this is due to the fact that these strata represent a slightly lower horizon than is exposed in Trilobite Dingle. The same graptolitic fauna is obtained from both localities. On the western side of the valley, the group is again found cropping out in the fields south of Brookland Hall. The best exposure here is seen in the dingle by Penbryn.

The upper beds here become massive mudstones, with flaggy bands towards the top. The beds are extremely fossiliferous in places, and contain lamellibranchs and graptolites in the lower and more shaly strata, while *Trinucleus* characterizes the mudstone group. The strata are again linked together by the occurrence of similar graptolites, which become more rare in the upper part of the group.

On the north they are again well exposed in Gwern Heylin, where the strike swings round to the west. A fault of unknown throw occurs just below the lake. This locality yielded practically no fossils.

If we follow the strike westwards as far as Guilsfield Brook, it brings us up against a river-cliff consisting of the Powis-Castle Conglomerate series. The whole of the Ordovician succession of Moel-y-garth ends abruptly against Silurian rocks here in Guilsfield Brook. Another huge fault, running north-east and south-west, occupies the bed of the stream. The throw is to the north-west, and is at least 2000 feet in amount. This fault may be appropriately named the Moel-y-garth Fault.

On this side of the valley, the Trilobite-Dingle Shales are not again well exposed until Middle House is reached, half a mile north of Guilsfield, where they are seen in the stream-section, although they must occur under the drift and alluvium covering the valley-floor. From this point they can be traced by Ceunant Mill to the northern limit of the map.

It is fairly certain that the lower beds of the Trilobite-Dingle Group are of Llandeilo age; but there is no sufficient palæontological or lithological break in the succession to enable us to draw the line.

List of Fossils from the Trilobite-Dingle Shales.	Trilobite Dingle.	Trelydan Dingle.	Penbryn Dingle.	Middle House Dingle.	Ceunant Mill.	Ranging locally into the overlying beds.
Asaphus powisi Murchison	×	...	...	...	...	×
Dionide sp.	...	...	...	×	...	...
Trinucleus concentricus Eaton	×	...	×	...	...	×
Trinucleus concentricus, var. _caractaci_ Murch.	...	...	×	×	...	×
*_Trinucleus concentricus_, aff. var. _portlocki_ Salter.	...	...	...	×	...	×
Trinucleus concentricus, cf. var. _arcuatus_ Smith	...	...	...	×	...	×
Trinucleus intermedius, sp. nov.	×	...	...	...	...	...
Trinucleus cf. _lloydi_ Murchison	...	...	...	...	×	...
Climacograptus schærenbergi Lapworth	×	...	×	...	...	...
Diplograptus (Amplexograptus) perexcavatus Lapw.	×	×	×	...	×	...
D. (Amplexograptus) arctus Elles & Wood	...	...	×	...	×	...
Diplograptus (Mesograptus) foliaceus Murch.	×	×	...	×	...	...
Diplograptus (Orthograptus) truncatus Lapw.	...	×	...	...	...	...
D. (O.) truncatus, var. _pauperatus_ Elles & Wood	...	×	...	...	...	...
D. (O.) pageanus, var. _micracanthus_ E. & W.	×	...	...	...	...	×
Bellerophon (Protowarthia) bilobatus Sowerby	×	...	...	...	...	×
Bellerophon sp.	×	...	×	...	...	...
Cyrtolites parvus Ulrich, var. _carinatus_ nov.	...	...	×	...	...	...
Ctenodonta coarctica Phillips	×	×	...	...	...	×
*_Ctenodonta lingualis_ Phillips	...	...	×	...	...	×
*_Ctenodonta antiqua_ Sowerby	...	...	×	...	...	...
Ctenodonta cf. _levata_ Hall	...	...	...	×	...	...
Ctenodonta sp.	...	...	×	...	...	...
Orthis sp.	×	...	×	...	...	...

---

* Fossils marked with an asterisk were collected by J. Bickerton Morgan.

(2) Pwll-y-glo Beds.—These are best exposed in the sharp ridge of Pwll-y-glo, half a mile west of the Welshpool Dyke. They consist of shales, mudstones, and flags, with some bands of hard grit. More or less regular alternations occur—consisting of 2 or 3 feet of shale, with seams of hard, greenish, micaceous grit varying in thickness from 3 to 12 inches. The beds which form the ridge are folded into an asymmetrical syncline, along an east-north-easterly and west-south-westerly axis. The most fossiliferous exposure is the second old quarry to the south-west of Pwll-y-glo Farm. About 100 feet of shales and flags are here exposed.

The beds strike north-eastwards along the ridge towards the Bron-y-Buckley Fault. Behind Groes-pluen Farm the series is seen to be folding over towards the north-west, whereas elsewhere along the ridge the dip is southerly or south-easterly.

On the south-west, the Pwll-y-glo Beds continue towards Y Frochas, where the strata are somewhat contorted, much jointed, and to some extent faulted. At Y Frochas, the outcrop turns round sharply to the north-east again, and can be traced along the flanks of Harriets Hill to Cloddiau. The valley between Pwll-y-glo and Harriets Hill is cut in the crest of an anticline in the Pwll-y-glo Beds.

Another faulted syncline occurs at Cloddiau, and the strike swings right round to the north-west, the dip being south-westerly. A good selection of fossils can be obtained in a quarry on the roadside between Cloddiau and Penbryn.

This series can now be traced round the eastern flanks of Moel-y-garth Hill, until it is cut out by the Moel-y-garth Fault.

North of Guilsfield this group is largely covered by drift. It begins to crop out again from under the drift at the foot of Trawscoed Rough, and is again well exposed in Gwern-y-brain and the eastern foot of Gaerfawr.

The fossils obtained from these beds clearly indicate a very low position in the Bala Series. Because of the transitional characters of the beds, I have considered them as a separate group. They represent a period of change between the deposition of the lower shales and the shallower-water types above. Their fauna is somewhat remarkable, since they contain few of the graptolites so abundant in the shales below; while brachiopods, which swarm in the beds above, are practically absent. (See List on p. 426.)

(3) Gaerfawr Group.—This constitutes the most important series of beds in the district. Wherever these beds crop out, they form sharp tree-covered ridges, usually crested by a crown of pines. Their escarpments are particularly steep and abrupt, and, since the strata invariably dip at somewhat high angles, the dip-slope is also fairly steep. This has probably led to their outcrops being almost invariably given over to woodland. The highest ridges in the area, Moel-y-garth and Gaerfawr, are so formed.

From lower beds.	LIST OF FOSSILS FROM THE PWLL-Y-GLO BEDS (see p. 425).	Pwll-y-glo.	Groes-pluen.	Lane near Y Frochas.	Well, Cloddiau.	Quarry between Cloddiau and Penbryn.	Ranging locally into the overlying beds.
×	*Asaphus powisi* Murchison	×	...	...	...	×	×
...	*Homalonotus bisulcatus* Salter	×	...	...	...	×	×
...	*Illænus* cf. *bowmanni* Salter	...	...	×	...	...	...
...	*Illænus davisi* Salter	...	...	...	...	×	...
...	*Salteria primæva* Thomson	×	...	...	×	...	...
×	*Trinucleus concentricus* Eaton	...	×	...	×	×	×
...	*Trinucleus* cf. *concentricus* Eaton	...	×	×	...	...	× ?
×	*Trinucleus concentricus*, var. *caractaci* Murch.	×	...	...	×	...	×
×	*Trinucleus concentricus*, cf. var. *portlocki* Salter	...	...	...	...	×	...
...	*Trinucleus fimbriatus* Murchison	×	...	...	...	...	...
...	*Trinucleus* aff. *nicholsoni* Reed	...	...	...	...	×	× ?
...	*Beyrichia (Tetradella) complicata* Salter	...	...	...	...	×	...
...	*Climacograptus* cf. *bicornis* Hall	×	...	...	...	...	...
...	*Diplograptus (Orthograptus)* cf. *rugosus*, var. *apiculatus* Elles & Wood	×	...	...	...	...	...
×	**D. (O.) pageanus*, var. *micracanthus* Elles & Wood	...	×	...	...	..	...
...	*D. (O.) calcaratus*, var. *vulgatus* Lapworth	...	...	...	×	...	...
...	*Cyathocrinus quinquangularis* Phillips	×	...	...	...	...	×
...	*Sphæronites* sp.	×	...	...	...	...	...
...	*Orthoceras vagans* Salter	×	...	...	...	...	...
...	*Bellerophon (Oxydiscus) acutus* Sowerby	×	...	...	...	...	...
...	*Carinaropsis acuta* Ulrich & Scofield	×	...	...	...	...	...
...	*Bellerophon (Protowarthia)* cf. *pervolutus* U. & S.	...	...	...	×	...	...
...	*Bellerophon (Protowarthia)* aff. *nodosus* Sow.	...	...	...	...	×	...
...	*Anodontopsis bulla* M'Coy	×	...	...	...	...	...
×	*Ctenodonta* cf. *coarctica* Phillips	×	...	...	...	...	...
...	*Ctenodonta* cf. *anglica* d'Orbigny	×	...	...	...	...	...
...	*Ctenodonta* cf. *longa* Ulrich	...	...	...	×	...	...
...	*Vanuxemia* sp.	...	...	×	...	...	...
...	*Orthonota* aff. *amygdalina* Sowerby	...	...	×	...	...	...
...	*Leptæna rhomboidalis* Wilck.	×	...	...	...	...	×
...	*Orthis (Dalmanella) testudinaria* Dalm.	...	...	...	...	×	×
...	*Orthis (Herbertella) vespertilio* Sowerby	...	...	...	...	×	...
...	Annelid tubes	×	...	...	...	×	×

* From J. Bickerton Morgan's Collection.

The Gaerfawr Group, consisting of hard, greenish, micaceous grits and flags with a few thin shale-partings, occupies the centre of the syncline which forms the ridge at Pwll-y-glo. Only a small thickness of the beds occurs here, the remainder having been removed by denudation. Across the valley, however, they form the wooded ridge of Harriets Hill, and terminate at a fault on the south at Y Frochas.

The grits cross the road at Cloddiau, and swing round so as to strike exactly at right angles to their direction in Harriets Hill. This change in the direction of the strike is very remarkable. It causes the ridge of Moel-y-garth to cut across the general line of all the surrounding hills in the district.

The great difference, besides the lithological distinction, between these beds and those already dealt with, is the presence of vast numbers of brachiopods. The lower beds yield very few species of *Orthis*, and such as are found are insignificant forms but poorly preserved as a rule. The deeper-sea conditions of the lower and more shaly beds evidently did not favour brachiopod life; but in this shallower-water type they appear to have flourished abundantly. Fossils can be obtained from numerous localities on Moel-y-garth, the chief locality being an old quarry at the western end of Moel-y-garth Wood. Good exposures also occur on the summit of the ridge itself and on its eastern flanks.

The grits of Moel-y-garth are cut off against Guilsfield Brook, where they form a magnificent fault-scarp. Since the Moel-y-garth Fault is a dip-fault, the lateral displacement is very considerable; and one has to proceed nearly half a mile on the northern side of the fault before the Gaerfawr Beds come in again at Groes-lŵyd, west of Guilsfield. Here the beds, broken off by the fault, come in again, forming another well-marked escarpment bounding the western side of the Guilsfield Valley, and having its finest development in the Gaerfawr ridge. The series crops out from under the Powis-Castle Conglomerate, striking now in the normal north-easterly direction and dipping usually at an angle of about 40° north-westwards. As the beds are traced to the north, it becomes very evident that a higher sequence is exposed than is seen in Moel-y-garth, and the unconformity of the overlying conglomerate series becomes distinctly noticeable.

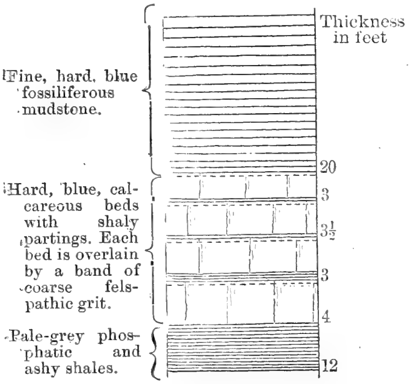
An old quarry in the field above Trawscoed Rough gives the best exposure of the middle strata of the Gaerfawr Series. About 50 feet of alternating massive grits and bastard-limestone bands are exposed. The 'limestones' are beds of sandy grit crowded with fossils, chiefly *Orthis*, of which only hollow casts remain. The hollows left by the removal of the calcium carbonate are filled as a rule with soft powdery limonite, which imparts to the rock a reddish-brown coloration.

In Gwern-y-brain, a complete section exposing about 1000 feet of grits and flags can be seen. Near the entrance to Gwern-y-brain by Twll, some faulting is observed, bringing the grits against the Pwll-y-glo Group. Farther up the valley, the beds roll slightly, and strike-faults occur: the exact thickness cannot, therefore, be measured. It seems very likely that it is greater than that mentioned above. A series of old quarries line the road up the valley, exposing hard massive grits. These contain few fossils, except in the occasional softer bands.

Two quarries, now being worked near the top of the valley, expose a higher series of the grits than I have seen elsewhere. The beds become, in fact, limestones, usually bluish in colour, and frequently impure and muddy. The lowest beds exposed rest

upon a thin stratum of pale ashy shales. About 50 feet of beds are exposed in the quarry, giving the following section (fig. 3):—

Fig. 3.—*Section near the top of the Gwern-y-brain Valley.*



The lower shale-band is phosphatic. The calcareous beds in the quarry are thick and massive. They are, as a rule, fine-grained, blue, and hard. Each thick bed has a curious structure, and it gradually passes upwards into a band of coarse whitish grit. A microscopic examination showed that each of these grit-bands was exceedingly rich in large angular fragments of remarkably fresh plagioclase-felspars, along with quartz-grains, sometimes a good deal of mica, and granules of fine-grained igneous rocks, of a basaltic or andesitic nature. Some of the igneous fragments are probably ashes. The fresh felspars and the andesitic fragments seem to indicate rapid denudation in a neighbouring volcanic area. A faulted monoclinal fold is seen in the eastern corner of the quarry; the throw is about 10 feet to the west. A second fault is seen on the west side of the quarry, throwing down again to the west; but the amount could not be measured.

The fossils, which are beautifully preserved, and often filled with milk-white calcite, correlate these upper beds very closely with the horizon of the Lower Bala Limestones both of North Wales and of South Wales, while the presence of ashy grits in them shows their intermediate character. The group is sharply defined on palæontological grounds. (See List on p. 429.)

(4) Gwern-y-brain Group.—This consists of a series of thin, fine-grained, jet-black shales, which readily splinter to fragments. Near the base in Gwern-y-brain occurs a band of black crystalline limestone. These beds are only fossiliferous at certain horizons, and occur over a limited area. They are seen above the Gaerfawr Limestone in Gwern-y-brain, and can be traced thence to the dingle below Trawscoed Hall. Here the outcrop seems to be shifted by a small fault; but shales can be traced along a depression towards Cross Wood, where they are overlapped by the Powis-Castle Series. The beds are crowded with inarticulate brachiopods and ostracods at certain horizons. Gasteropods also are very abundant; while articulate brachiopods, where present, are characteristically dwarfed.

From underlying beds.	LIST OF FOSSILS FROM THE GAERFAWR GRITS (see p. 428).	Moel-y-garth.	Fron-y-fele.	Old quarry above Trawscoed Rough.	Gaerfawr Quarry, Gwern-y-brain.	Ranging locally into the overlying beds.
×	*Asaphus* cf. *powisi* Murchison	...	...	...	×	...
...	*Asaphus* sp.	×	×	...	...	...
...	*Asaphus (Isotelus)* sp.	...	...	...	×	...
...	*Calymene blumenbachi* Brongniart	...	...	×	...	×
...	*Cybele* sp.	...	...	...	×	...
×	*Homalonotus bisulcatus* Salter	...	...	...	×	...
...	*Proetus* aff. *girvanensis* Nich. & Eth.	×	...	...	...	...
...	*Phacops (Chasmops) conicophthalmus* (Bœck) Salt.	×	...	...	...	...
...	*Phacops (Acaste) alifrons* Salter	...	×	...	...	...
...	*Phacops (Acaste) apiculatus* Salter	...	...	...	×	...
...	*Remopleurides* sp.	...	...	...	×	...
×	*Trinucleus concentricus* Eaton	...	×	...	×	×
×?	*Trinucleus* cf. *concentricus* Eaton	×	...	...	...	...
×	*Trinucl. concentricus*, var. *caractaci* Murch.	...	...	...	×	...
×	*Trinucl. concentricus*, aff. var. *arcuatus* Smith	×	...	...	...	...
...	*Trinucleus elongatus* Portlock	...	...	...	×	...
×?	*Trinucleus nicholsoni* Reed	×	...	...	...	...
...	*Trinucleus* sp.	...	...	...	×	...
×	*Bellerophon (Protowarthia) bilobatus* Sow.	...	×	...	...	...
...	*Bellerophon (Protowarthia) portlocki*, sp. nov.	...	...	...	×	...
...	*Cyclonema donaldi*, sp. nov. (see p. 453)	×	...	...	...	...
...	*Helicotoma* cf. *marginata* Ulrich	...	...	...	×	...
...	*Lophospira* cf. *serrulata* Salter	...	...	×	...	...
...	*Liospira* sp.	...	...	×	...	...
...	Tiny indeterminate gasteropod	...	...	...	×	...
...	*Tentaculites anglicus* Salter	×	...	...	...	×
...	*Glyptocrinus basalis* M‘Coy	×	×	...	...	...
...	*Glyptocrinus* sp.	×	×	×	×	...
×	*Cyathocrinus quinquangularis* Phillips	...	...	×	...	...
...	*Monticulipora fibrosa* Goldfuss	×	×	...	×	×
...	*Monticulipora lens* M‘Coy	...	×	...	...	×
...	*Monticulipora (?) ramosa* Goldfuss	...	...	...	×	...
...	*Ptilodictya (Stictoporella) costellata* M‘Coy	×	...	...	...	...
...	*Orthonota (Orthodesma) rigida* Sowerby	...	...	...	×	...
×	*Ctenodonta lingualis* M‘Coy	...	×	...	...	...
...	*Lingula attenuata* Sowerby	...	...	...	×	×
...	*Lingula ovata* M‘Coy	...	...	...	×	...
...	*Lingula* sp.	...	...	...	×	...
×	*Leptæna rhomboidalis* Wilck.	...	×	...	×	×
...	*Orthis* cf. *(Dinorthis) flabellulum* Sowerby	×	...	×	×	...
...	*Orthis calligramma* Dalm.	×	...	...	...	×
...	*Orthis calligramma* var. *plicata* Salter	×	...	×	...	×
...	*Orthis calligramma* var. *virgata* Sowerby	...	×	×	...	...
...	*Orthis (Herbertella) vespertilio* Sowerby	×	×	×	×	×
...	*Orthis (Herbertella) vespertilio* (Sow.) var.	...	...	...	×	...
×	*Orthis (Dalmanella) testudinaria* Dalm.	×	×	×	×	×
...	*Orthis (Dalmanella) elegantula* Dalm.	...	...	×	...	×
...	*Orthis (Plæsiomys) porcata* Sowerby	...	×	...	...	...
...	*Orthis (Plæsiomys) porcata*, var. *grandis* Portl.	...	...	...	×	...
...	*Orthis (Plæsiomys) porcata*, var. *inflata* Salt.	...	...	...	×	...
...	*Orthis* cf. *rustica* Sow.	...	×	×	...	×
...	*Orthis actoniæ* Sow.	...	...	×	...	×
...	*Orthis* cf. *intercostata* Portl.	...	...	×	...	...
...	*Plectambonites sericea* Sow.	×	×	...	×	×
...	*Plect. sericea*, var. *rhomboidalis* M‘Coy	...	×	...	×	...
...	*Plectambonites transversalis* Dalm.	...	...	...	×	×
...	*Platystrophia biforata*, var. *fissicostata* M‘Coy	...	...	×	...	×
...	*Rafinesquina expansa* Sowerby	...	...	×	...	...
...	*Strophomena pecten* Linn.	...	...	...	×	...
...	*Strophomena grandis* Sowerby	×	...	×	...	...
...	*Triplecia spiriferoides* M‘Coy	×	×	×	×	...
×	Annelid tubes	...	...	...	×	...

The Gwern-y-brain Series is not more than 50 feet thick. The limestone-band is only a few feet thick, and is unfortunately crystalline, yielding no fossils. It appears to correspond, in its stratigraphical position, with the *Staurocephalus* Limestone at the base of the Ashgillian. The overlying black shales are of the nature of passage-beds—since they contain *Trinucleus* cf. *seticornis*, associated with a peculiar assemblage of graptolites comprising forms which suggest an horizon, transitional between the Upper Hartfell and the Lower Birkhill, at which graptolites appear to be generally scarce and not well known.

The exact relation between these beds and the underlying grits is obscured by strike-faulting, while the Powis-Castle Conglomerate quickly overlaps them above. Obviously, it would be inconvenient to draw the line between the Ordovician and the Silurian in these shales; and therefore, since the fauna seems to justify this correlation, I have regarded them as being equivalent to the Ashgillian of Dr. Marr.

From underlying beds.	LIST OF FOSSILS GWERN-Y-BRAIN	From underlying beds.	FROM THE SHALES.
×	*Calymene blumenbachi* Brongn. (Ranges into overlying beds.)	...	*Conularia* cf. *aspersa* Lindstrœm.
...	**Trinucleus* cf. *seticornis* His.	...	**Eccyliomphalus bucklandi* Portlock.
...	*Bollia lata* Vanux. & Hall.	...	**Eccyliomphalus minor* Portlock.
...	*Ctenobolina ciliata* Emmons.	...	**Eccyliomphalus contiguus* var. *cambrensis*, nov. (see p. 454).
...	*Ctenobolina* cf. *ciliata* Emmons.	...	*Orbiculoidea perrugata* M‘Coy.
...	**Krausella arcuata* Ulrich.	...	*Orbiculoidea* cf. *perrugata* M‘Coy.
...	**Leperditia nana (?)* Jones.	...	*Orbiculoidea* cf. *crassa* Hall.
...	**Primitia humilis*, var. *humilior* Jones.	×	*Lingula attenuata* Sowerby.
...	**Primitia morgani* Jones.	...	*Lingula* cf. *brevis* Portlock.
...	**Primitia mundula*, var. *cambrica* Jones.	...	*Lingula obtusiformis*, sp. nov. (see p. 455).
...	**Primitia tumidula* Ulrich.	...	*Orbicula* cf. *terminalis* Conrad.
...	**Primitia* cf. *ulrichi* Jones.	...	*Obolella* sp.
...	**Primitiella unicornis* Ulrich, et var.	...	*Orthis hirnantensis* M‘Coy.
...	*Melanella hemidiscus*, gen. et sp. nov. (see p. 451).	...	*Orthis sagittifera* M‘Coy.
...	**Corynoides calycularis* Nicholson.	...	*Orthis intercostata* Portlock.
...	**Dendrograptus* sp.	×	*Orthis (Dalmanella) elegantula* Dalm. (Ranges into overlying beds.)
...	*Climacograptus* sp.	×	*Orthis* cf. *valpyana* Davidson.
...	**Diplograptus (Mesograptus) modestus*, cf. var. *parvulus* H. Lapw.	×	*Plectambonites sericea* Sowerby. } Range into overlying beds.
...	*Diplograptus (Orthograptus) truncatus*, cf. var. *socialis* Lapworth.	...	*Pl. transversalis* Dalm. }
...	*Diplograptus* sp.	...	*Trematis corona* Salter ?
...	*Glyptograptus persculptus* Salter.	...	*Siphonotreta micula* M‘Coy.

* From J. Bickerton Morgan's Collection.

It will be noted that out of 42 species only five range upwards from the beds below; four of these pass upwards also, being forms notable for their width of range. The fossil list thus strongly confirms the evidence afforded by the lithological character of the beds. It is evident that a remarkable change took place between the periods of shallow-water deposition during which

the Gaerfawr Grits on the one hand, and the Llandovery conglomerates on the other, were laid down.

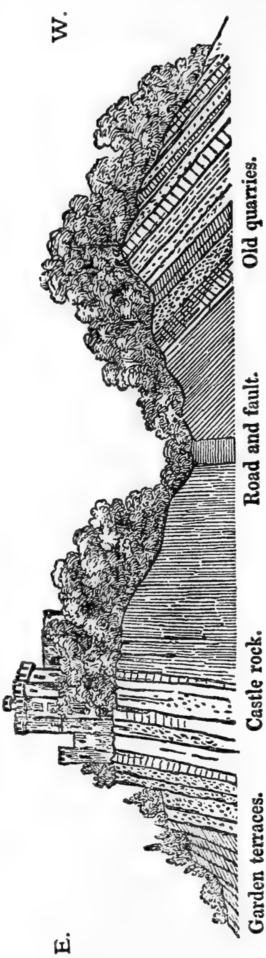


Fig. 4.—*Section reproduced from Murchison's 'Silurian System' 1839, p. 304.*

These beds do not crop out anywhere in the eastern portion of the area, except under the *Pentamerus* Limestone at Cefn near Buttington. A small outcrop of shales is exposed in the old quarries near Buttington Station. Here the strata fail to exhibit the peculiar character of the Gwern-y-brain Shales, and lack the jet-blackness which is so conspicuous in those beds. They are nearly vertical, and yielded *Climacograptus latus* (Elles & Wood), a graptolite which is typical of the highest horizon in the Bala Beds. The strata rest upon grits, which appear to belong to the Upper Gaerfawr Series.

(B) Silurian Rocks.

(1) Powis-Castle Group.—This important series of massive conglomerates, grits, and sandstones, with calcareous horizons, is well named after Powis Castle—since that structure is built of materials derived from these rocks, and is founded upon the finest exposure of them in the district.

In Powis Park, the series forms a sharp but broken anticline, on the eastern limb of which the Castle is built. Murchison was under the impression that these beds were the highest in his series of Caradoc Sandstones. I cannot do better than reproduce his section (fig. 4).

The western limb of the section is indistinctly lettered under the foliage. The beds are [1] *loc. supra cit.*:—

'*a.* Purplish-brown calcareous grit with many fragments of encrinites in beds, from 8 inches to one foot and a half, with wayboards of red shale, in parts a sandy and gritty, in others an encrinital and subcrystalline limestone.

b. Blotchy grit with much red shale.

c. Hard, fine-grained calcareous grit, passing downwards into a mottled, dingy green, and purple impure limestone with irregular traces of wayboards.

d. Purple and white limestone, with blotches of red shale.

e. Hard, fine, thick-bedded, calcareous conglomerate, red where weathered, but greyish when freshly broken. It consists of fragments of encrinites, green earth, chocolate-coloured schist, and a few quartz pebbles of sizes varying from small peas to almonds.

f. The lowest bed visible is a purple and whitish, semi-crystalline limestone, with white veins.'

The shales beneath this sequence belong to the Trilobite-Dingle Group.

The beds are much faulted in the Park, and vary considerably within a few yards. In some places most of them become a calcareous breccia. They are evidently a very shallow-water deposit, for evidences of contemporaneous denudation can be seen in the conglomerates.

Frequently the strata are stained a deep red, on account of being heavily charged with oxide of iron; but this is not always the case. When the series is traced to the south, towards Belan, it is seen to consist of yellow quartzose grits, which are soft, porous, and in places very fossiliferous. These beds come against the Bron-y-Buckley Fault, and are either partly concealed by it or are thinning out considerably. The conglomerates are seen in the fields on the crest of the ridge at Belan, where they apparently overlie beds yielding *Monograptus flemingi* and *M.* cf. *vomerinus*, etc., so that the line of the fault is easily determined.

The beds can be traced by the red nature of the soil in the direction of Welshpool. Where they cross the town, they cause a steep gradient in the main street.

A conglomerate, consisting largely of limestone fragments, forms the eastern wall of the Welshpool Dyke, in the quarries at the southern end: this almost certainly represents the Powis-Castle Conglomerate. It is altered by contact with the dyke-rock, but takes on its normal appearance again at Cherry-tree Bank, farther north, along the eastern flank of the Welshpool Dyke. Here the strata form a ridge running north-eastwards, and are exposed in two quarries—one on the Welshpool Golf-course, the other in Cherry-tree Bank itself. This ridge ends abruptly in both directions: on the east it is terminated by the Bron-y-Buckley Fault; while on the west it terminates in the fault which lets down the Welshpool Dyke. At Cherry-tree Bank the strata consist of red flaggy sandstones, conglomerates, and calcareous beds, all heavily charged with iron oxide, producing a red soil and staining the Trilobite-Dingle Shales beneath. Fossils are difficult to find, since the beds are fossiliferous on only one small horizon. This is in the quarry on the golf-course, and is the uppermost bed of quartzose conglomerate immediately under the turf. The beds are not seen again on this side of the valley. On being traced westwards, they are seen to thin out. A thin seam of conglomerate rests upon Pwll-y-glo Beds, near Ceunant Farm, in the gorge west of the Welshpool Dyke: it is let down by a fault which bounds that dyke again on this side. Farther west the beds crop out again, forming a broad anticline between the Welshpool Dyke and Cloddiau. The beds are again thicker and more massive on the western side of the fold. At Cloddiau,

between 20 and 30 feet of massive red quartzose conglomerate merges upwards into red sandy flagstones. The beds are very ferruginous, and contain large quartz-pebbles, green jaspers, fragments derived from the lower beds in the sequence, as well as pebbles of fine-grained igneous rocks of unknown origin. This conglomerate has been largely quarried for building-stone and road-metal, but it is now superseded by the rock from the Welshpool Dyke, and the upper calcareous beds of the Gaerfawr Series. At Cloddiau the group rests on a still higher horizon of the Caradocian rocks. The Lower Gaerfawr Grits crop out from under the conglomerate in Harriets Hill on the south; while on the north, higher beds still emerge in Moel-y-garth. The Conglomerate itself thins out as it is traced towards Y Frochas, where it loses its red coloration, and becomes a yellow grit resembling the Millstone Grit. The series ends abruptly here against a fault, and, owing partly to the thinning-out of the beds over the anticline, and partly to the overlap of the Ludlow Shales, it is not seen again between Y Frochas and Welshpool.

At Cloddiau the beds run north-westwards, resting against the western flanks of Moel-y-Garth, until they terminate against the Moel-y-garth Fault. Some faulting parallel and subsidiary to that fault disturbs them in places. At the place marked 'Laundry' on the map (Pl. XXXIII) they are overlain by about 40 feet of a grit which weathers in a peculiar manner. The unweathered grit is hard, blue, and calcareous, and runs in massive beds 6 to 10 feet thick, with wayboards of shale. When weathered, this grit becomes soft, crumbly, and chocolate-coloured, and it is only then that it reveals the fact that it is fossiliferous. The strata have evidently been disturbed, since the shale-bands between the grits are crumpled and broken in a complex manner.

On the western side of the Moel-y-garth Fault the beds come in again at Groes-lŵyd, and can be traced by Cross Wood to Trawscoed Hall, where they appear to thicken very greatly and form a wide outcrop. The apparent increase in thickness is due to gentle folding in the strata.

It will now be evident that this Conglomerate Series, which rests in turn upon every member of the Ordovician sequence, forms an excellent natural base to the Silurian strata of the district.

(2*a*) Cloddiau Group.—Above the Red Conglomerate Series from Cloddiau to the Laundry, there is exposed, chiefly in the roadside and in the stream-section which runs parallel to the road, a series consisting of 20 to 30 feet of blue shales overlain by about 200 feet of soft, sandy mudstones, with some siliceous flaggy bands. The beds are very fossiliferous in places, and were considered by Bickerton Morgan to be of Lower Wenlock age. The fossils obtained from them, however, proved them to be distinctly of Llandovery age. They are not well exposed, and appear to be quite barren in places. The fossils obtained near the Laundry would seem to indicate the presence of zones of both the Lower and the Upper Llandovery.

POWIS CASTLE GROUP.				LIST OF LLANDOVERY FOSSILS (see pp. 431–35).	CLODDIAU & CEFN BEDS.			Ranging into overlying beds.	CHRISTIANIA.[1]	
Powis Park.	Belan.	Cherry-tree Bank.	Laundry.		Cloddiau.	Llyswen.	Cefn.		Étage 6 (KIÆR). Lower Llandovery.	Étage 7 (KIÆR). Upper Llandovery.
...	...	×	...	*Calymene blumenbachi* Brong. (From underlying beds.)	...	...	...	...	...	...
...	...	...	...	*Climacograptus innotatus* Nicholson	×	...	...	...	...	...
...	...	..	...	*Climacograptus* cf. *rectangularis* M'Coy	×	...	...	...	...	...
...	...	...	...	*Climacograptus medius* Törnquist	×	...	...	...	...	...
×	...	...	...	*Duncanella* sp.?	...	...	...	...	...	...
×	...	...	...	*Favosites gothlandica* Goldfuss	...	...	...	...	×	×
×	...	×	...	*Favosites aspera* d'Orbigny	×	...	...	...	×	× (base)
...	...	×	...	*Favosites* sp.	...	...	×	...	...	...
...	...	×	×	*Lindstrœmia subduplicata* M'Coy	...	...	...	...	...	...
...	...	×	×	*Lindstr. subdupl.* var. *crenulata*, M'Coy	...	...	...	...	...	...
×	...	...	...	*Lindstrœmia* sp.	...	...	...	...	...	...
×	×	...	×	*Petraia bina* Lonsdale	...	...	...	...	...	...
...	...	×	...	*Petraia* aff. *elongata* Phillips	...	...	×	...	...	...
...	...	...	...	*Petraia* sp.	...	...	...	...	...	...
...	...	×	...	*Pinacopora grayæ* Nich. & Eth.	...	...	...	...	×	...
×	...	...	...	*Streptelasma europæum* Rœmer	...	...	...	...	...	...
×	...	...	...	*Streptelasma* sp. nov.? aff. *breve* Ulrich	...	...	...	...	...	...
...	...	×	...	*Syringopora* cf. *bifurcata* Lonsdale	...	...	...	...	...	×
×	...	...	×	*Monticulipora (?) fibrosa* Goldfuss. From underlying beds.	...	...	..	...	×	...
...	...	×	...	*Monticulipora lens (?)* M'Coy	...	...	...	...	...	...
...	...	×	...	*Callopora* sp.	...	...	...	...	×	...
...	...	×	...	*Ptilodictya dichotoma* Portl.	...	...	...	...	...	...
...	...	...	×	*Retepora hisingeri* M'Coy	...	...	...	...	×	...
...	...	×	...	*Stictoporella angularis* Ulrich	...	...	...	...	...	...
×	×	×	...	*Glyptocrinus* sp.	×	...	...	...	...	...
...	...	×	...	*Tentaculites anglicus* Salter. (From underlying beds.)	...	...	...	...	×	× (base)
...	...	...	...	*Cornulites serpularius* Schlotheim	...	...	×	...	...	...
...	...	×	...	*Murchisonia* cf. *gyrogonia* M'Coy	...	...	...	...	×	...
...	...	×	...	*Atrypa marginalis* Dalm.	×	...	...	...	×	...
...	...	...	...	*Atrypa reticularis* Linn.	×	...	×	...	×	×
...	...	×	...	*Camarotœchia decemplicata* Sowerby	×	...	...	...	×	...
...	...	×	...	*Camarotœchia nucula* Sowerby	×	...	×	×	...	...
...	...	×	...	*Dayia navicula* Sowerby	...	...	...	×	...	...
...	...	...	×	*Leptæna rhomboidalis* Wilck. (From underlying beds.)	×	...	×	×	×	×
×	...	...	...	*Lingula crumena* Phillips	...	...	...	...	...	...
×	×	×	...	*Meristella (?) crassa* Sowerby	...	...	...	...	×	× (base)
...	...	...	...	*Meristella (?) subundata* M'Coy	×	...	...	...	×	× (base)
...	...	...	...	*Meristella* sp.	×	...	...	...	...	...
×	...	...	...	*Meristina* cf. *tumida* Dalm.	...	...	...	...	...	×
...	...	...	...	*Orthis rustica* Sowerby. From underlying beds.	...	...	×	...	×	×
×	...	×	...	*Orthis (Dalmanella) testudinaria* Dalm.	...	...	×	×	...	×
×	×	×	×	*Orthis (D.) elegantula* Dalm.	×	...	...	×	×	×
...	...	×	...	*Orthis plicata* Sow.	...	...	...	...	...	...
...	...	...	...	*Orthis* cf. *calligramma* Dalm.	×	...	...	?	...	...

---

[1] Dr. Johan Kiær, in 'Das Obersilur im Kristianiagebiete' Christiania, 1908 (Vidensk.-Selsk. Skrifter I. Math.-Naturv. Klasse, 1906, pt. 2), has been able to divide the Llandovery into stages or zones in that area. I have therefore compared the ranges of the Llandovery fossils with those recorded by him. It will be noted that the Powis-Castle Group correlates very fairly with Dr. Kiær's Étage 6.

POWIS CASTLE GROUP.				LIST OF LLANDOVERY FOSSILS [*continued*] (see pp. 431–35).	CLODDIAU & CEFN BEDS.			Ranging into overlying beds.	CHRISTIANIA.	
Powis Park.	Belan.	Cherry-tree Bank.	Laundry.		Cloddiau.	Llyswen.	Cefn.		Étage 6 (KIÆR). Lower Llandovery.	Étage 7 (KIÆR). Upper Llandovery.
...	...	×	...	*Orthis calligramma*, var. *davidsoni* Lindstr.	...	...	...	...	×	×
...	...	×	...	*Orthis (Bilobites) biloba* Linn.	...	...	...	...	×	× (base)
...	...	...	...	*Orthis bouchardi* Dav. ?	×	...	...	...	...	...
...	...	×	...	*Orthis crispata* M'Coy	...	...	...	...	...	...
...	...	×	...	*Orthis reversa* var. *mullockiensis* Dav.	...	...	...	...	...	...
...	...	...	...	*O. (Herbertella) vespertilio* Sowerby. (From underlying beds.)	×	...	...	...	...	...
...	...	×	...	*Pentamerus (Barrandella) undatus* Sowerby	×	×	...	?	×	? (base)
×	...	×	×	*Pentamerus (Stricklandinia) lens* Sowerby	×	×	×	...	×	...
...	...	...	...	*Pentamerus oblongus* Sow.	...	×	×	...	...	×
...	...	...	...	*Pentamerus* cf. *lævis* Sow.	...	...	×	...	...	...
...	...	×	...	*Platystrophia biforata* Schlotheim. (From underlying beds.)	×	...	...	...	×	×
...	...	×	...	*Plectambonites* sp.	...	...	...	...	...	...
×	×?	...	...	*Rhynchonella llandoveriana* Davidson	×	...	...	...	...	...
...	...	...	×	*Rhynchonella* sp.	...	...	...	...	...	...
×	...	×	...	*Rhynchotreta borealis* Schlotheim	...	...	...	...	×	×
...	...	×	×	*Rhynchotreta cuneata* Dalm.	...	...	...	...	...	×
...	...	...	...	*Strophomena pecten* Linn.	...	...	×	...	×	...
...	...	...	...	*Strophomena corrugatella* Davidson	...	...	×	...	...	...
...	...	×	...	*Skenidium lewisi* Davidson ?	...	...	...	...	×	...
...	...	×	...	*Triplecia insularis* Eichwald	...	×	...	...	×	...
...	...	×	...	*Triplecia* cf. *nucleus* Hall	...	...	×	...	...	...

On tracing the strata round to Y Frochas, we note that they overlie the grits there in one or two old quarries where the road crosses the moorland. They consist of thickly-bedded mudstones, which are much cleaved and jointed. A few flags occur, but the whole series seems to be utterly devoid of fossils. In the neighbourhood of Powis Castle this horizon does not occur at all, being overlapped by the higher Silurian beds. The series can, however, be traced northwards, and yields fossils again in a small quarry at Llyswen: the strata here are similar to those at Cloddiau, but are not so thick, nor are the higher beds of the sequence exposed.

(2 *b*) Cefn Group.—The *Pentamerus*-Limestone beds at Cefn on the extreme east of the map, seem to represent a higher Llandovery horizon than the limestone associated with the Powis-Castle Group. The beds consist of massive grey calcareous grit, with brecciated limestone-bands and some thin beds of shale. The beds are much broken and contorted by the intrusion of an igneous rock which is similar to that of the Welshpool Dyke, and was formerly seen in the quarry-walls.

It will be noted that the fossils, on the whole, indicate an horizon nearer to Wenlock age than do those which are connected with the Powis-Castle Beds. It seems, therefore, that the limestone facies spread to this side of the valley at a later period than in the areas farther west.

(3) Buttington Shales.—The igneous rock intruded at Cefn forms a well-marked and isolated feature there. On the eastern side of the hill, the Buttington Brickworks Company have made a large quarry in a series of green and purple shales, with which are interbedded a few bands of hard green flags. About 300 feet of nearly vertical strata are exposed, but a careful search through the series yielded nothing beyond a few obscure ostracoda. From the position and lithological character of the strata, they would appear to be the equivalents of the Tarannon Shales. They crop out nowhere else in the district, whence it may be inferred that they either thin out westwards, or are overlapped by the succeeding Wenlock Shales: the former alternative seems the more probable. The beds exposed in the quarry show beautifully the effects of 'creep' at the surface (see Pl. XXXIV).

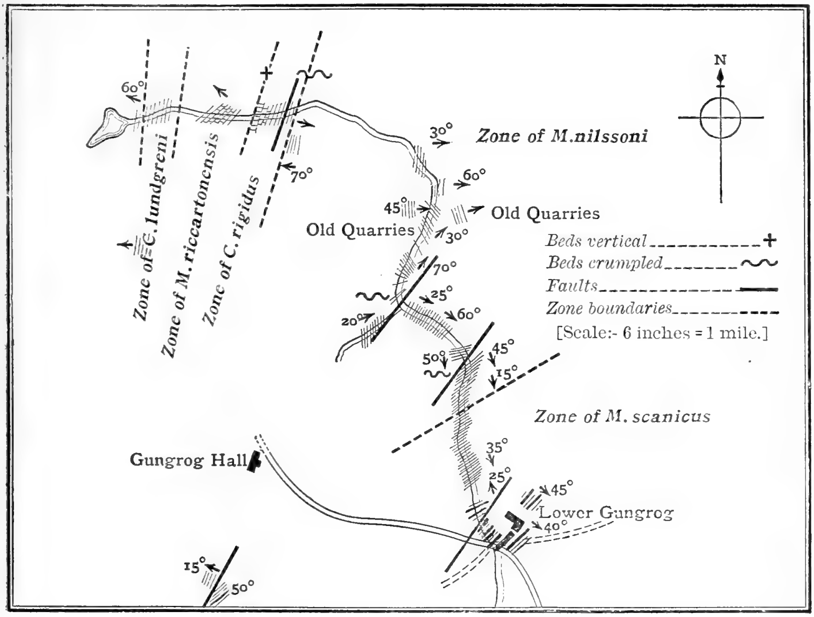
(4) Wenlock Shales (eastern facies.)—At Belan, south of Powis Castle, hard flags and mudstones containing fossils which indicate the lowest Wenlock zones seen in this area, are faulted against the Llandovery conglomerate. The beds weather brown, and are cleaved and well jointed, wherefore some care is necessary to distinguish the bedding-planes. Graptolites are to be found only on the edges of splinters. At the top of the hill, the Wenlock is overlain by the Lower Ludlow Shales, which now come against the fault that runs in a direction slightly transverse to the strike of the beds.

The beds are overlain by drift in the neighbourhood of Powis Park, but crop out again to the north of Welshpool, where they are best seen in Cwm Caethro, a small valley between the farms of Caethro and Lower Gungrog. Here the beds are much faulted and crumpled, with some evidence of overthrusting. Despite this disturbance, three well-defined Wenlock zones can be established (fig. 5, p. 437). The outcrop of the beds is very narrow, compared with that of the overlying Silurian; but no reliable estimate can be formed of their thickness. They consist of earthy mudstones and blue flags. The *Cyrtograptus-linnarssoni* Zone is probably concealed by faulting, while the zones of *C. murchisoni* and *C. symmetricus* usually seem to be absent in this part of the Welsh Borderland. Against these beds, by a small waterfall in the stream, come Lower Ludlow Shales, bearing *Monograptus varians* and *M. vulgaris*, the whole of the beds being crumpled and overfolded at the junction.

From Cwm Caethro, the series can be traced into Trelydan Dingle, at the head of which, just under Trelydan Cottage, strata of Wenlock age are to be seen folded into an anticline against the Trilobite-Dingle Shales. At first sight, the appearance suggests Llandeilo Flags, cropping out from under the *Dicranograptus* Shales; but the palæontological evidence proves the existence of a great fault at this point. The beds consist of a blue earthy limestone, containing in places numerous little cubes of pyrite, overlain by hard, calcareous, gritty flags. Only the limestone-band yielded fossils,

and these are indicative of Wenlock age, *Pentamerus linguifer* being most common. The exposure is very small, but it is interesting to find the Wenlock-Limestone facies extending to this district. The bed is only 2 or 3 feet thick, and may be merely a local development; it is very similar, however, in its lithological peculiarities to the Wenlock Limestone of Wenlock Edge.

Fig. 5.—*Map illustrating the exposures in Cwm Caethro.*

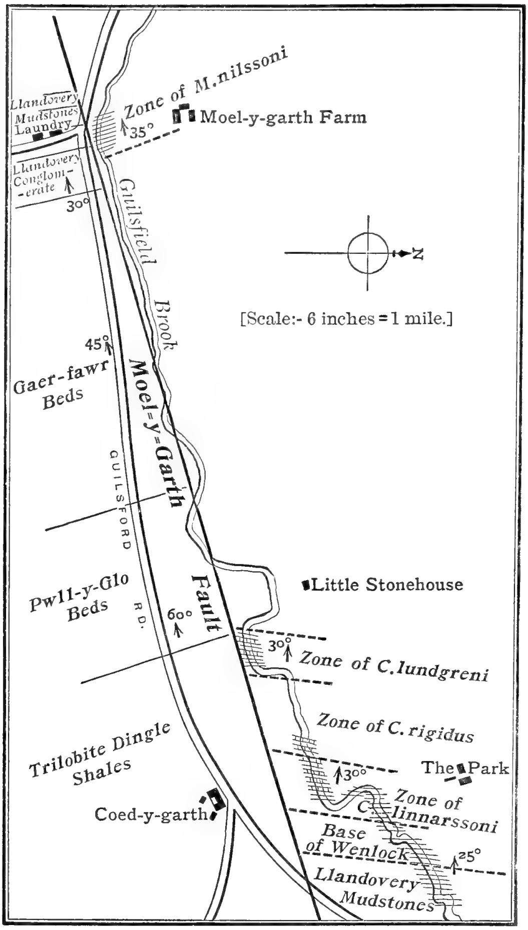


(Western facies).—Passing from the eastern side of the district over the anticline of Guilsfield Valley to the west, we find a most interesting outlier of Wenlock Shales resting directly upon Gaerfawr Beds at Tyn-y-llwyn, near Little Pwll-y-glo.

The graptolite fauna shows that shales of the zone of *Cyrtograptus lundgreni* were deposited over the anticline, contrasting with the Llandovery conglomerates which thin out over it. It is evident, therefore, that a folding movement had already commenced before the deposition of the Llandovery Series; and a ridge of Gaerfawr Beds, which are thin here and have evidently been much denuded, formed an island in Llandovery times. This ridge was finally submerged in the Upper Wenlock period; and it will be seen that the submergence was finally more complete in Lower Ludlow times, since the Upper Wenlock Beds along with the Llandovery Beds

are completely overlapped between Powis Castle and Y Frochas. In the stream-section running down the west side of Y Frochas to Ty-brith, strata of Wenlock age again occur. The basement beds are sandy flagstones, but above they change to blue flags and shales with massive mudstones, which contain what have been described as 'large concretions of limestone.' In this case, I doubt the concretionary nature of the fragments, but think rather that they are boulders of an early Wenlock or late Llandovery limestone, broken up during a period of denudation which accompanied the overlapping of the upper beds already noticed at Tyn-y-llywn. This is suggested by the fact that some of the blocks are brecciated limestones or limestone-conglomerates, which could hardly be concretionary.

Fig. 6.—*Map showing the Wenlock zones exposed in Guilsfield Brook.*



The circumstance that the zone of *Cyrtograptus lundgreni* rests upon these brecciated beds, shows that the overlap of the Wenlock Shales followed closely upon a period during which the Llandovery Beds were being subjected to denudation along the axis of the anticline. In Guilsfield Brook, between Coed-y-garth and the Park Farm, the zones of *Cyrtograptus linnarssoni*, *C. rigidus*, and *C. lundgreni* are fairly well seen (fig. 6); it is possible, however, that other zones may be present. Fragments

of *Cyrtograptus* are common in each of these zones, but many of them could not be determined.

The beds pass up into strata of Ludlow age, the zone of *Monograptus nilssoni* being observed near Moel-y-garth Farm.

(5) Yr Allt Group.—The Ludlow Shales form the most widespread division of Palæozoic rocks in the area. They are, as a rule, uniform in character, and consist, on the lower horizons, chiefly of pale thinly-bedded shales, soft and muddy, but tend to become hard, flaggy, and calcareous above. The highest beds are thin flaggy sandstones, but these are only seen in one locality, the top of the Yr Allt escarpment.

A surprising feature of these soft shales is the way in which they occupy the crests of the highest hills; but this is explained by the fact that, wherever they so occur, they are much faulted and crumpled. They appear to have suffered greatly in the movements which have affected the district, and in several places small overthrusts can be detected in the Wenlock and Ludlow. In the Cefn area, the beds have already been described by Miss Elles and Miss Wood (Mrs. Shakespear).

These beds form a long line of escarpment running north-north-eastwards from Belan to the Severn, broken in the middle by the Welshpool Gap,[1] in which they are hidden by drift and alluvium. The strata are folded against the Bron-y-Buckley Fault into a long narrow anticline and syncline. From the core of the anticline the Wenlock Shales crop out; but against the Bron-y-Buckley Fault a thin strip of Ludlow Shales is usually found. This is seen in the quarries on the top of the hill at Belan (where Ludlow Beds succeed Wenlock against the fault), and at the southern end of Bron-y-Buckley Wood.

Below Cwm Caethro the zone of *Monograptus scanicus* occurs opposite Lower Gungrog Farm, where the strata consist of strongly-jointed dark-grey mudstones and shales weathering brown (fig. 5, p. 437). They are broken by a couple of faults between the farm and the orchard. This zone extends into the orchard, where beds yielding *Monograptus varians*, var. β Wood, come in. Above the orchard, the zone of *M. nilssoni*, consisting chiefly of soft earthy shales, with occasional bands of harder mudstones, can be traced right up to the waterfall, where the stream leaves the uppermost wooded dingle.

Farther north, the strata are more flaggy and calcareous. They form a magnificent and bold escarpment in the cliffs of Yr Allt. The lower part of that escarpment is concealed beneath screes; the upper part, consisting of hard false-bedded flagstones with a few thin shaly horizons, has been well quarried in places. Few

---

[1] See my 'Note on the Glacial Geology of the Area,' to be published separately.

fossils occur, and these suggest the upper zones of the Lower Ludlow.

At Derwen-deg the shales are so well cleaved that the bedding-planes are hard to distinguish, but fragments of *Monograptus nilssoni* were found on the edges of splintered pieces. A thin series of calcareous sandy flags rests upon the hard flags of Yr Allt cliffs, in the lane-section about 300 yards north of Spout House. These beds yield myriads of *Dayia navicula*, together with an assemblage of fossils which suggests the horizon of the Aymestry Limestone[1] or the uppermost beds of the Lower Ludlow [10, p. 438].

In the Park of Powis Castle, the Ludlow Shales are seen on the west side of the Castle, resting almost directly upon the Powis-Castle Conglomerate Series. They form the highest ground in the Park, and are much crushed and contorted. They evidently overlap the Wenlock Series, or are brought in by a fault parallel and subsidiary to the Bron-y-Buckley Fault.

The beds form a high ridge, which runs north-north-eastwards to Nant-y-caws Brook. The country here is much covered by drift; but the Ludlow strata appear to swing round in a great curve to the west, overlapping the underlying beds on the axis of the Guilsfield Valley anticline. They form an escarpment running almost due east and west as far as Glyn, where it again takes up the north-easterly direction. North of Glyn, *Monograptus colonus* occurs in extraordinary abundance in some exposures. The graptolites are preserved in limonite probably after pyrite, and so their presence renders the beds quite rotten and crumbly.

The Lower Ludlow Beds cover a very wide tract on the west of the area, and numerous excellent exposures occur, notably near Trefnant and The Park. The strata are much folded; they consist of brown flags and shales, which pass upwards into blue flags containing an extraordinary number of calcareous concretions or septaria, locally called 'cannon-balls.' These differ considerably from the limestone-blocks seen in the Wenlock Shales at Ty-brith. The blue flags often contain numerous specimens of *Monograptus colonus* arranged in star-like patterns on the bedding-planes. Nearly the whole of this outcrop belongs to the zone of *M. nilssoni*, a species which is very abundant. This zone is evidently very thick—not less than 400 to 500 feet in the neighbourhood of Trefnant. The underlying zone is rarely exposed, and is apparently not so well developed. The rolling of the beds, however, renders accurate measurement difficult.

Higher zones are doubtfully present, although the barren flags of Tir-newydd are similar in character to the flaggy beds of the upper part of the Yr Allt escarpment, and may represent the upper division of the Lower Ludlow.

---

[1] Miss G. L. Elles & Miss I. L. Slater, 'The Highest Silurian Rocks of the Ludlow District' Q. J. G. S. vol. lxii (1906) p. 197.

LOCAL RANGE AND DISTRIBUTION OF THE WENLOCK AND LUDLOW GRAPTOLITES. [C=Common.]	LUDLOW.									WENLOCK.								
	Zone of *Monograptus leintwardinensis.*	Zone of *Monograptus scanicus.*		Zone of *Monograptus nilssoni.*					Zone of *M. vulgaris.*	Zone of *Cyrtograptus lundgreni.*				Zone of *Cyrtograptus rigidus.*		Zone of *C. linnarssoni.*	Zone of *Monograptus riccartonensis.*	
	Yr Allt.	Yr Allt.	Cwm Caethro.	Cwm Caethro.	Belan.	Guilsfield Brook.	The Park.	Trefnant.	Ty-brith.	Ty-brith.	Tyn-y-llwyn.	Cwm Caethro.	Guilsfield Brook.	Cwm Caethro.	Guilsfield Brook.	Guilsfield Brook.	Cwm Caethro.	Belan.
Monograptus dubius Suess	...	...	...	×	...	...	...	...	...	×	×	...	...	...	...	C	...	...
Monograptus comis Wood	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...
Monograptus vulgaris Wood	...	...	...	...	...	...	...	...	×	...	×	...	...	...	...	...	...	...
Monograptus vulgaris, var. *β* Wood	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Monograptus colonus Barrande	...	...	...	C	C	C	C	×	...	...	...	...	...	...	...	...	...	...
Monograptus colonus, var. *compactus* Wood	...	...	...	...	×	...	×	...	...	...	...	...	...	...	...	...	...	...
Monograptus colonus, var. *ludensis* Murchison	...	...	...	...	...	...	C	...	...	...	...	...	...	...	...	...	...	...
Monograptus varians Wood	...	...	...	×	×	×	...	...	...	...	...	...	...	...	...	...	...	...
Monograptus varians, var. *β* Wood	...	...	...	C	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Monograptus varians, var. *pumilus* Wood	...	×	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Monograptus chimæra Barrande	...	...	C	...	...	×	...	...	...	...	...	...	...	...	...	...	...	...
Monograptus leintwardinensis Hopkinson ?	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Monograptus nilssoni Barrande	...	...	...	×	×	×	...	C	...	...	...	...	...	...	...	...	...	...
Retiolites spinosus Wood	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...
Cyrtograptus lundgreni Tullb.	...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...
Monograptus flemingi (Salt.), var. *α* Elles	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	...	×
Monograptus flemingi (Salt.), var. *δ* Elles	...	...	...	...	...	...	...	...	...	×	C	C	C	...	...	...	...	...
Cyrtograptus rigidus Tullb.	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...	...	...	...
Cyrtograptus linnarssoni Lapworth	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C	...	...
Monograptus galaensis Lapworth	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
Monograptus riccartonensis Lapworth	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...
Monograptus vomerinus (Nich.), var. *α* Elles	...	...	...	...	...	...	...	...	...	×	...	...	...	...	×	...	...	×

	Wenlock.			List of Wenlock and Ludlow Fossils other than Graptolites.	Ludlow Shales.					
Ty-brith.[1]	Trelydan Dingle.	Cwm Caethro.	Belan.		Belan.	Gungrog.	Yr Allt.	Spout House.	Powis Park.	Trefnant.
...	...	...	×	*Phacops longicaudatus* Murchison	...	...	...	...	...	...
...	...	...	...	*Ceratiocaris pardoëana* La Touche	...	...	...	...	...	×
...	...	...	...	*Orthoceras primævum* Salter	×	×	×	...	×	×
...	...	×	...	*Orthoceras subundulatum* Portlock	...	×	...	...	...	...
...	...	...	...	*Orthoceras gregarium* Sowerby	...	...	...	...	...	×
...	...	...	...	*Orthoceras canaliculatum* Sowerby	×	...	...	...	...	...
...	...	...	...	*Orthoceras* cf. *imbricatum* Wahl.	...	...	...	...	×	...
...	...	...	...	*Orthoceras* sp.	×	...	...	...	...	...
...	...	...	...	*Phragmoceras nautileum* Sowerby	×	...	...	...	...	...
...	...	...	...	*Lituites cornu-arietis* Sowerby	×	...	...	...	...	...
...	...	...	...	*Camarotœchia* cf. *nucula* Sowerby	...	...	...	×	...	...
...	...	...	...	*Dayia navicula* Sowerby	...	...	...	×	...	...
×	...	...	...	*Leptæna rhomboidalis* Wilck.	...	...	...	...	...	...
...	...	...	...	*Orthis* cf. *actoniæ* Sowerby	...	...	...	×	...	...
...	×	...	...	*Pentamerus linguifer* Sowerby	...	...	...	...	...	...
×	...	...	...	*P. (Barrandella) undatus* Sowerby	...	...	...	...	...	...
×	...	...	...	*Plectambonites sericea* Sowerby	...	...	...	...	...	...
...	×	...	...	*Rhynchonella* sp.	...	...	...	...	...	...
×	...	...	...	*Strophomena* cf. *filosa* Sowerby	...	...	...	...	...	...
×	...	...	...	*Spirifer* cf. *concinnus* Hall	...	...	...	...	...	...
...	×	...	...	*Wilsonia wilsoni* Sowerby	...	...	...	...	...	...
...	...	...	...	*W. wilsoni*, cf. var. *sphæroidalis* M'Coy	...	...	...	×	...	...
...	...	...	...	*Cardiola interrupta* Brod.	×	...	×	...	×	×
...	...	...	...	*Pterinea retroflexa* Wahl.	...	×	...	...	...	...
...	...	...	...	*Pterinea tenuistriata* M'Coy	...	×	...	...	...	...
...	...	...	...	*Cornularia subtilis* Salter	...	...	...	...	...	×
...	...	...	...	Ostracoda	...	...	...	×	...	×

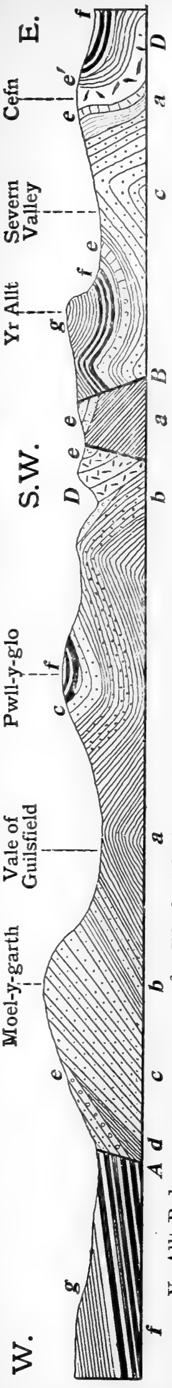
[1] These beds are possibly of Llandovery age. (See p. 438.)

VI. Structure of the Area. (Section III, fig. 7, p. 443.)

The structure of the two valleys dealt with in these pages is by no means simple. Broadly speaking, the strata are folded into two parallel anticlines with north-north-easterly and south-south-westerly axes, the eastern anticline occupying the Valley of the Severn, and the western the Vale of Guilsfield. Between the two is a crush-zone, consisting of two smaller anticlines crushed against the Bron-y-Buckley Fault, and separated by the Welshpool Dyke. The Welshpool Dyke is probably of the nature of a horst, carrying with it the Trilobite-Dingle Shales, while Silurian strata are let down on either side.

The Bron-y-Buckley Fault is practically a strike-fault, and so there is but little lateral displacement of the outcrops. The amount of the throw can be surmised by the fact that, at the entrance to Trilobite Dingle, Ludlow Shales are thrown against the Trilobite-Dingle Beds. Since, however, we must allow for the

Fig. 7.—*Generalized section from east to west, illustrating the structure of the area.*



g = Yr Allt Beds.
d = Gwern-y-brain Shales.
A = Moel-y-garth Fault.
f = Wenlock Beds.
c = Gaerfawr Grits.
B = Bron-y-Buckley Fault.
e' = Tarannon Shales.
b = Pwll-y-glo Beds.
D = Dyke.
e = Powis-Castle Beds.
a = Trilobite-Dingle Shales.

fact that the Llandovery Beds here rest directly upon the Trilobite-Dingle Shales, the throw is only to the extent of the thickness of the Llandovery and Wenlock—probably about 500 feet on the east.

On the western side of the district, the Moel-y-garth Fault lets down the Silurian to the west, and the throw seems to be of greater amount than that of the Bron-y-Buckley Fault. The Moel-y-garth Fault is a dip-fault, and causes a displacement in the outcrop of upwards of half a mile, bringing Wenlock zones against the Caradocian of Moel-y-garth. The direction of this fault seems to be the normal one of the district, and several subsidiary faults run parallel to it.

The two main faults would appear to come together under the alluvium to the north of Guilsfield, and this effect is what might be called a 'keystone-fault,' or 'inverted trough-fault': the former term is perhaps the more expressive.

I am of opinion that some of the apparent overlap of the Silurian beds, especially the Ludlow Shales, is probably due to overthrust accompanying normal faulting. This is difficult to prove, on account of the nature of the beds; but it is a significant fact that, wherever these soft and rotten Ludlow Shales occur, they occupy high ground and are much contorted and crushed. Small overthrusts can readily be distinguished, especially in Cwm Caethro; but the overthrusting suspected would be on a larger scale. It seems probable that, in the movements which brought about the folding and faulting of the area, the lower and more consistent beds bent or broke under the pressure, while the soft shaly beds above would tend to move forward over the beds beneath. This phenomenon can be seen on a small scale, in almost any quarry where hard beds including shaly bands are folded. Such overthrusting in the Silurian beds has been noticed by Prof. Reynolds in the Tortworth Inlier,[1] and by the present

---

[1] 'On the Fossiliferous Silurian Rocks of the Southern Half of the Tortworth Inlier' F. R. C. Reed & S. H. Reynolds, Q. J. G. S. vol. lxiv (1908) p. 535.

writer in the southern end of the May-Hill Inlier.[1] The Silurian strata do, however, overlap the lower beds, each group in turn creeping over the underlying group.

The overlap of Powis-Castle Beds has already been traced across the map. It is accompanied by the thinning-out of these beds over the anticline of the Guilsfield Valley. This is first suspected on account of the disappearance of the conglomerates and associated beds between Welshpool and Y Frochas, is confirmed by the fact that the conglomerate is only represented by a very thin bed (perhaps a foot or two thick) on the west side of the Welshpool Dyke in the Ceunant gorge, and is absolutely proved by the outlier of Wenlock Shales at Tyn-y-llywn, which rests directly upon the Gaerfawr Grits with no intervening Llandovery Beds. Here, therefore, the conditions are exactly the same as at Rhayader, where Dr. Herbert Lapworth has accounted for peculiarities in the distribution of the Llandovery (Caban) Conglomerate in the same manner.[2]

It would seem, then, that the whole of the Welsh Border was dotted with a chain of islands in Llandovery times, due to the fact that folding along north-easterly and south-westerly axes had already commenced. The Llandovery conglomerates were laid down in the synclinal depressions, and this accounts for the rapid changes noted in both the thickness and the lithological characters of the beds over limited areas. The islands were submerged locally in Wenlock times, and the overlap of the Ludlow, shown at the southern end of the map (Pl. XXXIII), which is probably true overlap, indicates further subsidence at a later period.

VII. Correlation of the Strata.

In attempting to correlate the sequence with that of other areas, I paid visits to other Welsh and Border districts—so as to make my comparisons, as far as possible, dependent on personal observation.

(1) Shelve.—It would naturally be expected that a close similarity would exist between the Ordovician succession in the Welshpool area and that of Shelve, only 6 miles away to the south-east. Nothing, however, could be more different. The Rorrington Flags may correspond to the Trilobite-Dingle Shales; but the alternating shales and ashes above them have no counterpart in the Welshpool area, unless it be in the ashy grits which occur along with the limestone development in the Gaerfawr Grits of Gwern-y-Brain. These may correspond to the Whittery Group.

(2) Caradoc.—Travelling 20 or 30 miles to the south-east, we come to an outcrop of Ordovician rocks which agrees tolerably well with the succession here described. The sequence in the Caradoc

---

[1] During field-work under Prof. W. W. Watts in 1907.

[2] 'The Silurian Sequence of Rhayader' Q. J. G. S. vol. lvi (1900) p. 117.

area itself is surprisingly like that succession.[1] It appears, however, that the succession in South Shropshire is not complete. Representatives of the Pwll-y-glo Group do not seem to occur, while the Ashgillian has not previously been recognized. I would, however, correlate the black shales of Gwern-y-brain with the *Trinucleus* Shales of the Onny River, placing the latter in the Ashgillian of Dr. Marr. This I have confirmed, and I may here record for the first time the fact that I have found *Diplograptus (Orthograptus) truncatus* var. *socialis* in considerable numbers in the *Trinucleus* Shales. This would correlate the horizon with the Barren Mudstones and the zone of *Dicellograptus complanatus* at Dobbs Linn, and would place them in the lower part of the Ashgillian. It would seem, therefore, that the Shelve area was in all probability isolated from the Welshpool district in Caradoc times, just as it was from the Caradoc area, and that the beds in the former area were laid down in a northern extension of the Caradoc Sea which swept round the Longmynd. If this be so, there is in all probability a prolongation of the Longmynd ridge under the Long Mountain.

(3) The Long Mountain.—The Silurian succession in the Long Mountain [7] [9] [10] is similar in most details to that of the Welshpool area. The graptolitic zones, absent in the Long-Mountain succession, are absent here also. There are, however, one or two points of difference, the principal being the occurrence of limestones, locally, in the Wenlock Shales. Nor does the zone of *Monograptus vulgaris* seem to be so well developed in this western area; otherwise the zones correspond fairly well.

(4) South Wales.—The strata here are easily correlated, although deep-water conditions seem to have lasted in South Wales right through the Caradocian period. Unfossiliferous black shales, overlying beds with *Trinucleus seticornis* and underlying mudstones which contain fossils somewhat similar to those of the Powis-Castle Beds, occur near Haverfordwest, and may represent, in part, the similar shales of Gwern-y-brain.[2]

(5) Central Wales (Rhayader).—There are some points of resemblance and some points of difference between the succession at Rhayader[3] and the sequence at Welshpool. The characters of the 'cleaved black slates' agree almost entirely with those of the black shales of Gwern-y-brain. In Gwern-y-brain, however, they are not cleaved and are, in places, very fossiliferous. Moreover, at Rhayader, these black slates apparently pass up conformably into

---

[1] C. Lapworth & W. W. Watts, 'The Geology of South Shropshire' Proc. Geol. Assoc. vol. xiii (1894–95) pp. 312, 319–20.

[2] F. R. C. Reed, 'The Base of the Silurian near Haverfordwest' Geol. Mag. dec. 5, vol. iv (1907) pp. 535 *et seqq.*

[3] H. Lapworth, 'The Silurian Sequence of Rhayader' Q. J. G. S. vol. lvi (1900) pp. 124 *et seqq.*

the lowest member of the Valentian, and the unconformity with accompanying conglomerates occurs later. In Gwern-y-brain, the unconformity along with the conglomerate stage appears to occur at, or very near, the base of the Valentian. Other points of similarity between the two areas have already been mentioned.

(6) North Wales.—On visiting the Bala area itself, I found many points of similarity; but, although the work of Thomas Ruddy[1] established the general succession in this area, the subdivision of the sequence and its exact correlation still remain to be done. The lists of fossils from the Lower Bala Limestone of Bala are closely comparable with those drawn up from the limestone horizon in the Gaerfawr Grits. I have, therefore, chosen the succession worked out by Miss Elles at Conway[2] as presenting the most complete sequence that I could get in North Wales for comparison. Shales predominate in that district, yielding many graptolite horizons, whereas shallower-water conditions existed at Welshpool and graptolites are not so abundant; and yet there is a good deal of similarity between the palæontological succession in both areas.

(7) The Lake District.—Curiously enough, it is when we come to the Lake District and the Scottish (Girvan) area, that we find the closest and most complete similarity, especially in lithological characters.

There are many points of resemblance in the lower part of the sequence developed in the Lake District. The limestone development in the Gaerfawr Grits seems to correspond very well with the Applethwaite Limestone; while the position and characters of the Ashgill Shales and *Staurocephalus* Limestone are very similar to those of the Gwern-y-brain Shales and Limestone. The unconformity, seen at the top of the Ashgillian in the Welshpool area, does not appear to be present in the typical area, and so the Powis-Castle Group can only be correlated on palæontological grounds.

(8) Southern Scotland (Girvan area).—Here, again, the sequence is similar. There are some surprising similarities in the palæontological character of the beds: for instance, the abundance of gasteropods at certain horizons in the Caradocian. The Pwll-y-glo Beds probably correspond to the Ardwell Flags, the graptolites present in them indicating that horizon.

VIII. Igneous Rocks—The Welshpool Dyke.

The physical characters of the Welshpool Dyke have been very fully described by Murchison [1]. I have little to add to his account, so far as its texture and appearance are concerned. It illustrates very well the internal structure of a large dyke, and is

---

[1] Q. J. G. S. vol. xxxv (1879) pp. 200–208. See also A. J. Jukes-Browne, Student's Handbook of Stratigraphical Geology' 1902, pp. 109–12.

[2] Q. J. G. S. vol. lxv (1909) pp. 171–72.

N OF THE ORDOVICIAN AND SE OF OTHER AREAS.

North-Eastern Montgomeryshire.		District.	Southern Scotland (Girvan Area).
	Zones of		
Allt Beds.	4. *M. leintwardinensis ?* 3. *M. scanicus.* 2. *M. nilssoni.* 1. *M. vulgaris.*	gs. its.	Mudstones and shales of Lanark.
nlock ales & estone.	4. *Cyrtogr. lundgreni.* 3. *C. rigidus.* 2. *C. linnarssoni.* 1. *M. riccartonensis.*	gs.	Straiton and Bargany Beds.
ttington Shales.		ds.	Parkhill Group.
ddiau Mudstones.			
vis-Castle Conglomerate and imestones.		s.	Canregan Group. Saugh Hill Group. Mullock Hill Group.
nconformity.)		Beds ?	
vern-y-brain Group.	Black shales. Limestone.	es. *lus* stone.	Drummuck Beds (with *Staurocephalus*).
erfawr Group.	Limestone and ashy grits. Grits and flags.	pplethwaite Limestone. onglomerate. tile-End Beds.	Shallock Flags. Whitehouse Beds. Ardwell Flags.
l-y-glo Group.			Balclatchie Beds. Grits and sandstone. Shales.
obite-Dingle Shales.			

TABLE ILLUSTRATING THE CORRELATION OF THE ORDOVICIAN AND SILURIAN ROCKS OF NORTH-EASTERN MONTGOMERYSHIRE WITH THOSE OF OTHER AREAS.

Series.		South Wales.	North-Eastern Montgomeryshire.	Caradoc.	Central Wales (Rhayader).	North Wales (Conway).	Lake District.	Southern Scotland (Girvan Area).
SALOPIAN.	LUDLOW.		Yr Allt Beds. Zones of 4. *M. leintwardinensis?* 3. *M. scanicus.* 2. *M. nilssoni.* 1. *M. vulgaris.*				Coldwell Flags. Coldwell Grits.	Mudstones and shales of Lanark.
	WENLOCK.		Wenlock Shales & Limestone. 4. *Cyrtogr. lundgreni.* 3. *C. rigidus.* 2. *C. linnarssoni.* 1. *M. riccartonensis.*			Benarth Flags and Grits.	Brathay Flags.	Straiton and Bargany Beds.
VALENTIAN.	TARANNON.		Buttington Shales.		Rhayader Pale Shales.	Gyffin Shales.	Browgill Beds.	Parkhill Group.
	UPPER LLANDOVERY.	Green mudstones & grits.	Cloddian Mudstones.		Caban Group.			
	LOWER LLANDOVERY.	Shales and sandstones. Unfossiliferous black shales.	Powis-Castle Conglomerate and Limestones.		(Unconformity.) Gwastaden Group.	Conway-Castle Grits.	Skelgill Beds.	Canregan Group. Saugh Hill Group. Mullock Hill Group.
ASHGILLIAN.		Slade Beds. Redhill Beds. Sholeshook Limestone. Robeston Wathen Limestone.	(Unconformity.) Gwern-y-brain Group: Black shales. Limestone.	*Trinucleus* Shales.	Cleaved black shales.	Deganwy Mudstones. Bodeidda Mudstones.	*Phyllopora* Beds? Ashgill Shales. *Staurocephalus* Limestone.	Drummuck Beds (with *Staurocephalus*).
CARADOCIAN.		*Dicranograptus* Shales.	Gaerfawr Group: Limestone and ashy grits. Grits and flags. Pwll-y-glo Group.	Acton-Scott Beds. Longville Flags. Chatwell & Soudley Sandstones. Hoar-Edge Grits. Harnage Shales.		Upper Cadnant Shales.	Sleddale: Applethwaite Limestone. Conglomerate. Stile-End Beds. and Roman-Fell Group.	Shallock Flags. Whitehouse Beds. Ardwell Flags.
GLENKILN-HARTFELL.			Trilobite-Dingle Shales.			Lower Cadnant Shales.		Balclatchie Beds: Grits and sandstone. Shales.

made up of parallel layers of roughly hexagonal columns, each column sloping a few degrees from the horizontal. The walls separating the layers are almost vertical, dipping about 80° to the east of south-east (see Pl. XXXV, fig. 2). The rock is fine-grained and light green in colour, with a specific gravity of 2·72, when fairly fresh. Under the microscope the structure is trachytic : the rock is seen to consist of small idiomorphic plagioclase-felspars arranged in lines of flow, with a certain amount of chloritic ground-mass, and a few tiny grains of augite where the rock is fairly fresh. Small patches of chlorite (probably ripidolite) show a radiating arrangement, when examined under the higher powers of the microscope (see fig. 8, below). Some grains of magnetite, pyrite, and graphitic material occur; while calcite becomes so abundant near the walls of the dyke, that the rock will effervesce with acid. The last-named mineral has evidently been derived from the calcareous breccia or conglomerate, which is seen resting against the eastern face of the dyke. The chlorite is probably the decomposition-product of a ferromagnesian mineral. There is an entire absence of porphyritic constituents, which were also absent primarily.

Fig. 8.—*Bostonite of the Welshpool Dyke, showing radiating aggregates of chlorite-crystals.*

[Magnified 50 diameters.]

The rock is somewhat similar to that of the intrusive dykes of Cefn and the Breiddens, where the original ferromagnesian mineral was described by Prof. Watts as being hypersthene [4] [7] [12]. These rocks have also been discussed by Mr. H. S. Jevons [11], who,

finding the felspathic constituent to be albite, suggests that the rocks are not diabases, as Prof. Watts had called them, but keratophyres. In order to settle this point with regard to the rock of the Welshpool Dyke, I first made several tests with the felspars. Using Becke's method, I obtained results which indicated albite. Not being satisfied, I employed microchemical tests. By means of Boricky's methed—using a 4 per-cent. solution of hydrofluosilicic acid—I obtained weakly double-refracting hexagonal crystals of sodium silicofluoride (Na_2SiFl_6) in great numbers, together with isotropic cubes and octahedra indicating potassium silicofluoride. Finally, I decided to make a series of analyses of the whole rock. The results indicate a rock nearer to bostonite than to keratophyre, and this would agree better with the microscopic characters. The absence of porphyritic constituents, the presence of marked flow-structure, and the fact that the rock is intrusive, are all in favour of it being called a bostonite, and against the term keratophyre being used in connexion with it. Mr. Jevons, in fact, states that an occurrence described by him from the Berwyn Hills is probably the first recorded of an intrusive keratophyre, while bostonites typically occur in dykes. I append the analyses, together with those of recognized bostonites obtained from two other localities: it will be seen how closely the results agree.

COMPARISON BETWEEN ANALYSES OF THE WELSHPOOL-DYKE ROCK AND SIMILAR ROCKS FROM OTHER LOCALITIES.

Constituents.	*Welshpool (No. 1).*	*Welshpool (No. 2).*	*Bostonite. Cowal.*[1]	*Bostonite. Orkneys.*[1]
SiO_2	54·17	54·15	56·4	52·00
Al_2O_3	12·96	17·97	19·0	18·06
Fe_2O_3	5·09	2·06	3·5	2·18
FeO	6·49	5·50	4·8	5·14
MgO	2·94	0·66	1·5	2·84
CaO	9·00	10·44	2·6	4·59
Na_2O	1·52	1·42	4·5	3·78
K_2O	5·64	5·55	5·0	4·68
H_2O	0·62	0·64	2·6	1·84
TiO_2	1·09	1·25	......	0·98
CO_2	......	......	......	3·59
MnO	......	......	......	0·25
Totals	99·52	99·64	99·9	99·93

---

[1] F. H. Hatch, 'Text-Book of Petrology' 5th ed. (1909) p. 231.

IX. Notes on the Palæontology of the Area.

(1) Trilobita.

Trinucleus intermedius, sp. nov. (Pl. XXXVI, figs. 1 & 2.)

Trinucleus concentricus Hall, 'Palæontology of New York' vol. i (1847) p. 249 & pl. lxv, figs. 4 *a*–4 *c*; also p. 255 & pl. lxvii, figs. 1 *a*–1 *h*.

Length = 18 mm.; width = 21 mm. General form almost circular. Head-shield semicircular, widest across the junction with the body-segments.

Fringe flat or concave in front, sloping downwards at about 60° at the genal angles, where it is produced backwards into long ears which reach to the tail. Spines straight and parallel, continued beyond the tail to a distance equal to the length of the main part of the test. Glabella pyriform and swollen, not equal in width to the cheeks, encroaching slightly in front on the fringe, posteriorly carinate. Base of the glabella narrow, with an obscure neck-furrow, which is continued along the posterior edge of the cheeks, where it bends abruptly at the margin of the ears. Cheeks swollen and wide, quite smooth. In the anterior part of the fringe are five rows of pits, the three posterior rows being of equal size, the two outer rows smaller. The three inner rows are concentric and radial; in the outer two rows the pits are smaller and more numerous, and therefore some of them take positions intermediate to the radii of the inner rows. The two innermost rows are separated from the others on the lower surface of the fringe by a ridge which runs round to the genal angles. At the genal angles, and in the space between the front of the glabella and the cheeks, the number of pits increases: in the former case to seven rows, in the latter case to six. The fringe has a thick flattened rim or edge along its outer margin.

The body is equal in length to the tail, but both together are only two-thirds of the length of the glabella and fringe. The body consists of five or six flat joints, the axis alone being convex. The first three joints are overlapped at their margins by the ears of the fringe. The axis is narrow, about a sixth of the width of the thorax. Pleuræ narrow, horizontal and flat, but curving slightly backwards at their outer extremities. They are grooved with a furrow which is almost parallel with the edges of the pleuræ. Pygidium subtriangular and flat; anterior margin slightly rounded and thickened. Axis conical and elevated; markings of rings and furrows on tail very obscure.

Remarks.—This remarkable species is readily distinguished from *Trinucleus concentricus*[1] by the large pendent ears of the fringe and the direct backward extension of the spines. The front of the fringe is more evenly semicircular than in *Tr. concentricus*,

---

[1] J. W. Salter, Q. J. G. S. vol. iii (1847) pp. 251 *et seqq.* [The *Trinucleus ornatus* there described is now recognized as *Tr. concentricus.*]

while its concave character also serves to distinguish it. The carinated glabella, too, is a characteristic feature.

From *Trinucleus lloydii*[1] it is distinguished by the subtriangular tail, which approximates in shape to that of *Tr. concentricus.* The concavity of the fringe is not so marked as in *Tr. lloydii*, while the indentations in the furrow surrounding the glabella in that species are either obscure or absent. The arrangement of the pits in the fringe is also different: in *Tr. lloydii* the pits are more closely set on the inner margin, while in *Tr. intermedius* they are more closely set on the outer margin of the fringe. The species is distinctly intermediate in character between *Tr. concentricus* and *Tr. lloydii.*

Hall's figures of *Tr. concentricus* seem to be nearer to *Tr. lloydii* than to *Tr. concentricus.* They correspond with *Tr. intermedius* more closely than with either, and differ chiefly in having shorter spines. The species figured in his pl. lxv differ also in the disposition of the pits, the larger pits being on the outside of the fringe. Those figured in his pl. lxvii correspond more closely in this respect. The grooves in the furrow, round the glabella, characteristic of *Tr. lloydii* are obscurely indicated in Hall's figures. The tail, however, is subtriangular, and the glabella encroaches on the fringe, both features characteristic of *Tr. intermedius*, and not of *Tr. lloydii.* On the whole, therefore, Hall's species correspond more closely to the species now described, although they are slightly nearer to *Tr. lloydii* than is the new species, thus affording a further link in the chain of evolution.

Horizon and locality.—Trilobite-Dingle Shales, Welshpool.

DIONIDE sp.? (Pl. XXXVI, fig. 3.)

Length = 11·8 millimetres; width = 12·5 mm. Shape nearly circular. Head equal in length to rest of body. Glabella large, almost circular, slightly contracted behind; somewhat swollen, bearing two pairs of furrows, more or less obscure, which die out towards the axis of the glabella. Cheeks about equal in width to the glabella, and bearing a groove which runs directly forward from the posterior margin at about a quarter of its length from the glabella, and meeting the glabella in its widest part. Anterior part of head-shield not preserved.

The body consists of six flat segments, the axis being slightly raised and rather more than a fifth of the width of the thorax. Pleuræ straight and horizontal, grooved by a strong diagonal furrow which divides them unequally.

Pygidium rounded or subtriangular, with entire margin. Axis conical, and bearing eight or nine rings which become small and obscure anteriorly. There are six lateral lobes, each somewhat fusiform in shape and grooved diagonally in a manner similar to

---

[1] J. W. Salter, 'Brit. Organic Rem.' Mem. Geol. Surv. dec. vii (1853) pl. vii.

that of the pleuræ. The lobes are separated by distinct furrows, which broaden towards the margin of the tail.

Remarks.—The species is somewhat like *Ampyx nudus*,[1] but the shape and character of the tail distinguish it from that species. It bears a rather close resemblance also to *Dionide richardsoni*[2]; but its broad shape, the narrow flattened tail, and the grooves in the cheeks are all points of difference. I believe the form to be a new species; owing, however, to the imperfect state of the head, I have hesitated to name it.

Horizon and locality.—Trilobite-Dingle Shales, Middle House Dingle, Guilsfield.

(2) **Ostracoda.**

Genus MELANELLA, nov.

Preoccupied - Renamed
by Baker 1924 who proposed
Vogdesella instead. [illegible]

Jonesella (pars) Ulrich, Journ. Cinc. Soc. Nat. Hist. vol. xiii (1890–91) p. 121.

Carapace small, equivalve, moderately convex, subcircular, rather flattened anteriorly; hinge straight; valves with a small, faintly-raised horseshoe ridge confined to the posterior half, enclosing a small semicircular sulcus. Edges simple.

This genus is closely allied to *Jonesella* of Ulrich, and less intimately to *Bollia* of Jones & Holl.[3] In the latter genus the horseshoe ridge is larger and more central, while the edges of the valves are thickened. In *Jonesella* the loop is a well-developed ridge, which is usually confined to the posterior half or two-thirds, but it occupies a greater portion of the valve than it does in *Melanella*. I have reproduced Ulrich's figure of *Jonesella crepidiformis* for comparison (see fig. 9 *c*, p. 452). *Jonesella obscura* Ulrich is most closely allied to the present form, and should be placed in the new genus. Ulrich, in describing this species,[4] shows plainly the need for a new genus here. He calls *J. obscura* 'an incipient *Jonesella*,' and shows that it has characters which are allied both to *Bollia* and to *Ulrichia*.

MELANELLA HEMIDISCUS, gen. et sp. nov. (Figs. 9 *a* & 9 *b*, p. 452.)

Length $=0{\cdot}76$ millimetre; height $=0{\cdot}65$ mm.

Valves moderately convex, almost semicircular in outline. Hinge straight and rather short, slightly rounded at the ends. Horseshoe ridge low and obscure, entirely within the post-dorsal half, enclosing a sulcus which contains a low tubercle. The species differs from *Melanella (Jonesella) obscura* in the more semicircular

---

[1] E. Forbes, 'Brit. Organic Rem.' Mem. Geol. Surv. dec. ii (1849) pl. x.

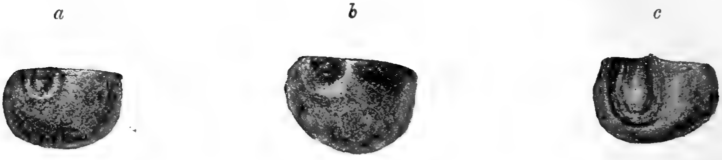
[2] F. R. C. Reed, 'Lower Palæozoic Trilobites of the Girvan District, Ayrshire' Monogr. Pal. Soc. (1903–1906) p. 26 & pl. iv, figs. 3–8.

[3] T. R. Jones, 'On some Devonian & Silurian Ostracoda from North America' Q. J. G. S. vol. xlvi (1890) pp. 540, 548 & pls. xx–xxi.

[4] 'Geology of Minnesota' Geol. Nat. Hist. Surv. Minn. vol. iii, pt. 2 (1897) pp. 667, 668.

shape of the valve, in the fact that the dorsal margins of the loop are not so prominent, and in the presence of a slight tubercle within the sulcus enclosed by the loop. I have figured Ulrich's species for comparison.

Fig. 9.—Melanella hemidiscus *gen. et sp. nov.* (*a* & *b*) *and* Jonesella crepidiformis *Ulrich* (*c*).



[Magnification = about 15 diameters.]

Horizon and locality.—Black shales of Gwern-y-brain.

In addition to the species just described, several others occur in the Gwern-y-brain Shales, which are new to British geology. The following brief notes will serve to record their chief characters:—

Primitiella unicornis Ulrich. (Pl. XXXVI, figs. 4 & 5.)

This species has already been described by the late Prof. Jones from specimens obtained by Bickerton Morgan from the Gwern-y-brain Shales. There are, however, one or two distinct varieties present which are referable to this form.

Var. 1 differs from the type-form in having a tubercle placed centrally, as well as a sulcus in the anterior fourth of the hinge-line. (See Pl. XXXVI, fig. 4.)

Var. 2 is distinctly punctate, with one large pore placed in a central position anteriorly with a slight sulcus behind it. (See Pl. XXXVI, fig. 5. Unfortunately the punctation does not show distinctly enough in the figures reproduced in this Plate.)

Primitia ulrichi Jones.

This species corresponds in shape and size with the late Prof. Jones's specimen, but differs in having a slight sulcus about half-way along the hinge-line.

Primitia tumidula Ulrich.

This specimen is a trifle larger than the species described by Ulrich, otherwise it possesses similar characters.

Ctenobolina cf. ciliata Emmons. (Pl. XXXVI, fig. 6.)

The shales provided both a typical specimen and a distinct variety, which is smaller and differs in the anterior ridge being small and separated from the central ridge. It may almost be considered a new species.

BOLLIA LATA (Vanuxem & Hall).

This species differs only from the type in the horseshoe ridge becoming less marked in the ventral region.

KRAUSELLA ARCUATA Ulrich.

Bairdia (Krausella) anticostensis of Jones closely resembles this specimen, but its more acute shape allies it more nearly to Ulrich's species.

(3) Gasteropoda.

CYCLONEMA DONALDI, sp. nov. (Pl. XXXVI, figs. 7–9.)

Shell subconical. Height and width approximately equal, about 12 millimetres. Apical angle = about 60°. A vertical plane through the apex of the shell would cut it into two unsymmetrical parts, one side sloping at a greater angle than the other. Whorls, four well preserved, with a rudimentary fifth; nucleus absent. The whorls are convex, with a slight concavity towards the top of each whorl, where it meets the succeeding one. This line of junction is slightly oblique to the horizontal. Revolving ridges or striæ absent, but the whorls are marked with fairly strong, oblique, transverse lines about 1 mm. apart, parallel to the margin of the aperture.

This species is closely allied to *Cyclonema sublæve* of Ulrich,[1] but the revolving lines present in that species are absent here. The oblique ridges, too, are more strongly developed; while the slight concavity in the upper part of each whorl also serves to distinguish it. Moreover, the angle of the spire is rather more obtuse.

Trochus constrictus of M'Coy[2] is very like this species in most respects. It is, however, a larger and more symmetrical form. In M'Coy's species the whorls are nearly horizontal, so that each whorl is almost centrally placed with regard to the succeeding one.

On these grounds I venture to name the species after Miss Jane Donald (Mrs. G. B. Longstaff), who has done so much research-work upon the Palæozoic gasteropoda.

Horizon and locality.—Gaerfawr Grits, Old Quarry, Moel-y-garth Wood.

BELLEROPHON (PROTOWARTHIA) PORTLOCKI, sp. nov. (Pl. XXXVI, figs. 10–12.)

Height = 27 millimetres; width at mouth = 20 mm.; width at the opposite extremity = 9 mm.; breadth = 14 mm.

Shell elongate, elliptical in section about the plane which cuts it symmetrically. Closely coiled, leaving practically no umbilicus. The whorls expand rapidly, until at maturity a fairly abrupt expansion gives rise to a wide aperture, which appears to have been

---

[1] 'Geology of Minnesota' Geol. Nat. Hist. Surv. Minn. vol. iii, pt. 2 (1897) p. 1062 & pl. lxxviii, figs. 48–49.

[2] 'British Palæozoic Fossils' 1855, p. 296 & pl. i K, fig. 41.

somewhat bilobate. Slit-band absent. This species might easily be mistaken for *Bellerophon (Protowarthia) bilobatus* of Sowerby. It differs, however, in the rapid expansion of the aperture, a feature which allies this form to the genus *Salpingostoma* of Rœmer. But the absence of a slit-band and the slight umbilicus place it in the subgenus *Protowarthia.* It is most closely allied to *Bellerophon elongatus* of Portlock.[1] The nature of the aperture is a distinguishing feature, while the species is smaller than that of Portlock. It is, however, so near to it that I have ventured to name the new species after him.

Horizon and locality.—Gaerfawr Grits, New Quarry, Gwern-y-brain.

CARINAROPSIS ACUTA Ulrich & Scofield. (Pl. XXXVI, figs. 13–15.)

'Geology of Minnesota' Geol. Nat. Hist. Surv. Min. vol. iii, pt. 2 (1897) p. 928 & pl. lxii, figs. 6–9.

This shell appears to be new to British palæontology. It is fairly common in the Pwll-y-glo Beds, and agrees in detail with the species described by the authors from the Ordovician shales of Minnesota. Two specimens are figured—the first a mature form, the second a young variety.

Horizon and locality.—Pwll-y-glo Beds, Second Old Quarry, Pwll-y-glo.

ECCYLIOMPHALUS CONTIGUUS Ulr., var. CAMBRENSIS nov. (Pl. XXXVI, fig. 16.)

The shell is 15 millimetres high and 10 mm. broad. It consists of three rapidly enlarging contiguous whorls, coiled so as to have a deep umbilicus. The outer whorl embraces the inner one, so that only a small portion of the inner whorl is seen. The lower lip of the aperture curves downwards on to the inner whorl.

The surface is covered with very fine and regular striæ, parallel with the edge of the aperture. The species is very similar in size and in general characters to Ulrich's *Eccyliomphalus contiguus.*[2] It differs, however, in having a narrower umbilicus and in being more finely and more regularly marked. It is, nevertheless, so near to Ulrich's species that I consider it to be simply a variety, such as one would expect to occur over the wide geographical area which separates the localities from which the specimens have been obtained.

Horizon and locality.—Very common in the black shales of Gwern-y-brain.

---

[1] 'Report on the Geology of Londonderry, &c.' 1843, p. 397 & pl. xxix, figs. 4 *a*–4 *b*.

[2] 'Geology of Minnesota' Geol. Nat. Hist. Surv. Min. vol. iii, pt. 2 (1897) p. 1037 & pl. lxxiv, figs. 48–52.

Cyrtolites parvus Ulrich, var. carinatus nov. (Pl. XXXVI, fig. 17.)

This pretty little fossil corresponds closely with Ulrich's species.[1] It differs, however, in having a distinct and well-defined keel, which is absent in the type-specimen. This is so well-marked a feature that I have named the Welsh variety *carinatus*.

Horizon and locality.—Trilobite-Dingle Shales, Penbryn Dingle.

(4) Brachiopoda (Inarticulata).

Lingula obtusiformis, sp. nov. (Pl. XXXVI, figs. 18 & 19.)

The two specimens figured are respectively 7 and 4·8 millimetres long, and 5 and 3·6 mm. broad.

Shell almost oval in shape, narrowing slightly at the beak. Almost flat, very slightly raised on the umbones. Beak not placed at the extreme posterior border as in most species of *Lingula*, but completely surrounded by the margin of the shell. The posterior portion of the valve is bisected by a strong median septum. The surface of the shell is covered with strong concentric ridges, parallel with the margin and sometimes showing stronger lines of growth. In addition to the concentric ridges, radial striæ also occur.

This species corresponds most closely with *L. obtusa* of Hall[2]; but the ribbings are much more pronounced, and the median septum is not seen in that species. It has also apparently some affinity to *L. coburgensis* of Billings.[3] The characters of the shell seem to be sufficiently distinct to warrant the formation of a new species; and, because of the close relationship to *L. obtusa*, I propose to call this species *Lingula obtusiformis*.

Horizon and locality.—Gwern-y-brain Shales, Guilsfield.

(5) Corals.

Streptelasma (?) aff. breve Ulrich. (Pl. XXXVI, figs. 20 & 21.)

Height = 18 millimetres; width across cup = 26 mm. Corallum free, simple, conical, slightly curved, and expanding very rapidly. Width greater than height. Surface marked with strong annulations and rather pronounced vertical ribs. Calyx deeply concave, extending to about a third of the height from the rim of the corallum. Septa large and small: total number of septa = about 72. The septa reach to the centre of the calyx, but the internal structure is not seen. The species is very like *Streptelasma breve* Ulrich,[4] but is larger, straighter, and possesses a more shallow calyx.

Horizon and locality.—Powis-Castle Beds, Powis Park.

---

[1] 'Geology of Minnesota' Geol. Nat. Hist. Surv. Minn. vol. iii, pt. 2 (1897) p. 864 & pl. lxii, figs. 45–47.

[2] 'Palæontology of New York' vol. i (1847) p. 98 & pl. xxx, figs. 7 *a*–7 *c*.

[3] 'Palæozoic Fossils' Geol. Surv. Canada, vol. i (1861–65) p. 50, fig. 54; 'Geology of Canada' Rep. Progr. Geol. Surv. Can. 1863, p. 161 & fig. 132.

[4] 'Geology of Minnesota' Geol. Nat. Hist. Surv. Minn. vol. iii, pt. i (1895) pp. 92 & 93, figs. 7 *a*–7 *d*.

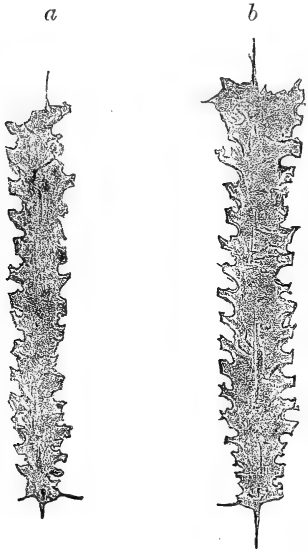
(6) **Graptolites.**

The graptolites are mostly forms which have been described fully by Miss Elles and Miss Wood (Mrs. Shakespear), either in the works already mentioned [9] & [10], or in their monograph on the British Graptolites still in progress.

Figs. 10 *a* and 10 *b*, however, seem to be slight variations upon *Diplograptus (Amplexograptus) perexcavatus* Lapw. The enlarged figures show the extraordinary spiny and irregular nature of the thecæ. This is commonly seen in the species from Trelydan and Sale Dingles.

Fig. 11 represents an interesting young specimen of *Monograptus vulgaris* from the Tyn-y-llwyn outlier. The chief point of interest is in connexion with the sicula. The early stages of the graptolite suggest in a surprising manner *Corynoides calicularis* of Nicholson.[1]

Fig. 10.—Amplexograptus perexcavatus *Lapw., magnified 5 diameters.*



[Both specimens are from Trelydan main dingle, about 100 yards down.]

Fig. 11.—*Young form of* Monograptus vulgaris, *magnified 5 diameters.*

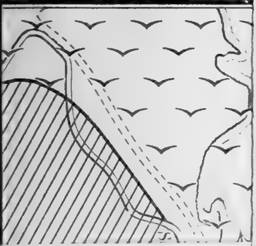
[The specimen is from Tyn-y-llwyn.]

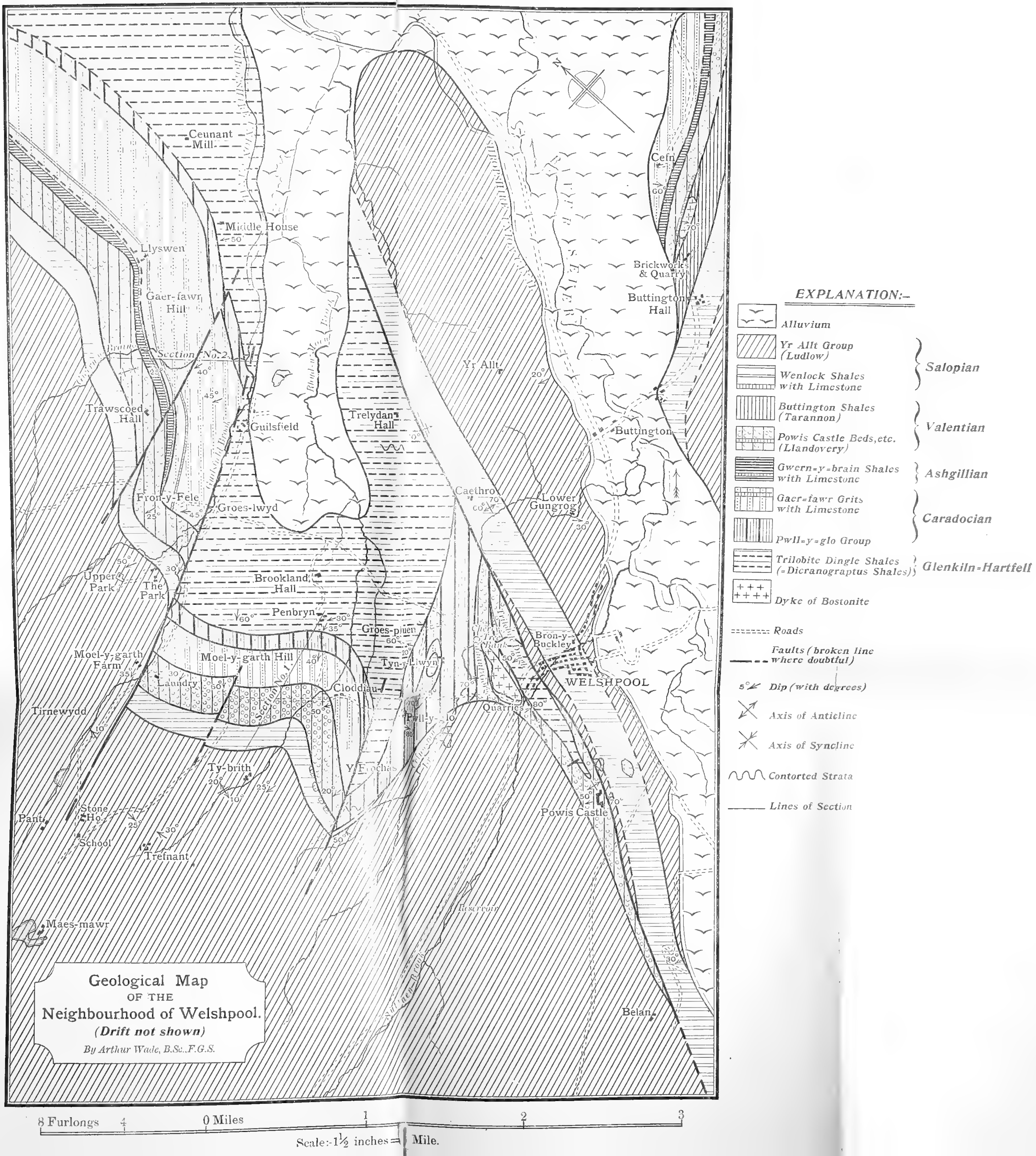
In concluding the notes on the palæontology of the area, I should like to mention a feature which this study has indicated. Wherever shales and deep-water deposits occur in the sequence, there is a remarkable influx of types which are common to the similar

---

[1] 'Monogr. Brit. Graptolitidæ' London, 1872, p. 132, fig. 74.

Quart. Journ. Geol.




Geological Map
OF THE
Neighbourhood of Welshpool.
(Drift not shown)
By Arthur Wade, B.Sc., F.G.S.
EXPLANATION:-
Alluvium
Yr Allt Group (Ludlow)
Wenlock Shales with Limestone
Salopian
Buttington Shales (Tarannon)
Powis Castle Beds, etc. (Llandovery)
Valentian
Gwern-y-brain Shales with Limestone
Ashgillian
Gaer-fawr Grits with Limestone
Pwll-y-glo Group
Caradocian
Trilobite Dingle Shales (=Dicranograptus Shales)
Glenkiln-Hartfell
Dyke of Bostonite
Roads
Faults (broken line where doubtful)
5° Dip (with degrees)
Axis of Anticline
Axis of Syncline
Contorted Strata
Lines of Section
Ceunant Mill
Middle House
Llyswen
Gaer-fawr Hill
Section No. 2
Trawscoed Hall
Guilsfield
Trelydan Hall
Fron-y-Fele
Groes-lwyd
Upper Park
The Park
Brookland Hall
Penbryn
Groes-pluen
Moel-y-garth Farm
Moel-y-garth Hill
Laundry
Section No. 1
Cloddiau
Tyn-y-Llwyn
Pwll-y-glo
Tirnewydd
Ty-brith
Y Foches
Stone Ho.
Pant
School
Trefnant
Maes-mawr
Reservoir
Yr Allt
Caethro
Lower Gungrog
Bron-y-Buckley
WELSHPOOL
Quarries
Powis Castle
Belan
Cefn
Brickworks & Quarry
Buttington Hall
Buttington
RIVER SEVERN
N
8 Furlongs 4 0 Miles 1 2 3
Scale:-1½ inches = 1 Mile.

A. W., *Photo.*] [*Bemrose Collo.*

QUARRY-SECTION IN THE BUTTINGTON SHALES, SHOWING THE HIGH INCLINATION OF THE STRATA.

FIG. 1.—IGNEOUS AND FELSPATHIC FRAGMENTS IN THE UPPER GAERFAWR GRITS.

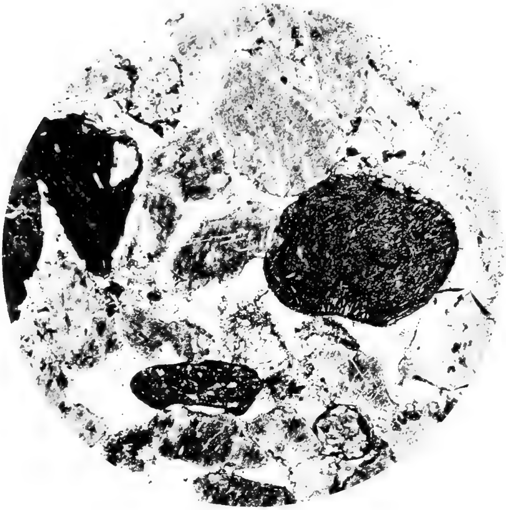
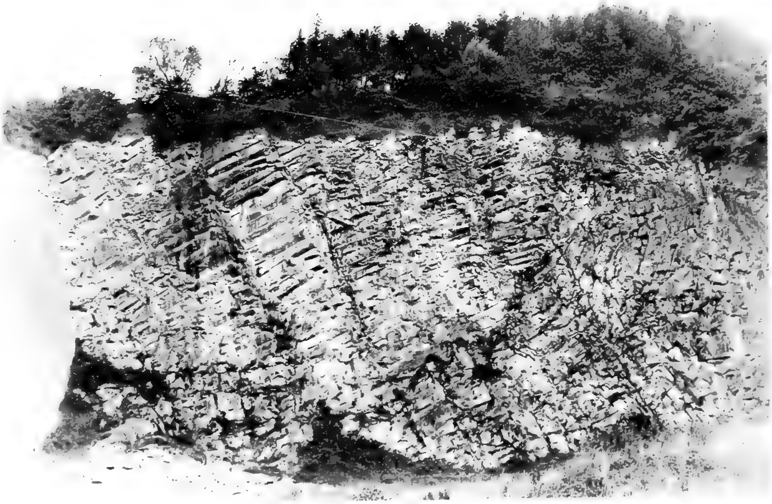


FIG. 2.—THE WELSHPOOL DYKE.



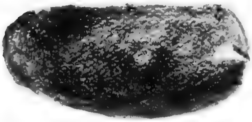
A. W., Photo.] [Bemrose Collo.

1

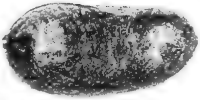
2

3

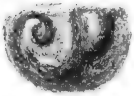
4



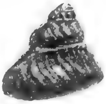
5



6

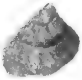


7

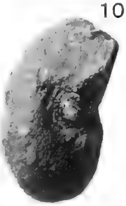


8

9

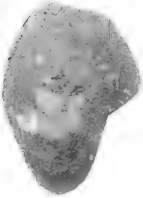


10



11

12



13

14

15

16

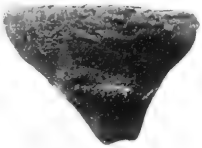
17

18

19

20

21



A. W., del. et photo.

Bemrose Ltd., Collo., Derby.

UPPER ORDOVICIAN AND LOWER SILURIAN FOSSILS
FROM NORTH-EAST MONTGOMERYSHIRE.

deposits of both Britain and America. The fossils of the grits and the shallower-water types in general are more distinctively British. This, of course, is a phenomenon which might have been expected.

The fossils described will be offered to the Museum of Practical Geology, Jermyn Street; while the remainder of the collection will remain in the Geological Laboratories of the Imperial College of Science & Technology.

Concluding Remarks.

In conclusion I desire to express my gratitude to Prof. Watts, at whose suggestion I entered upon this work, and from whom I have received much encouragement and advice. My sincere thanks are also due to Prof. Lapworth, who kindly placed at my disposal much of the material collected by the late Mr. Bickerton Morgan.

EXPLANATION OF PLATES XXXIII-XXXVI.

Plate XXXIII.

Geological map of part of North-Eastern Montgomeryshire, on the scale of an inch and a half to the mile, or 1 : 42,240.

Plate XXXIV.

Quarry-section in the Buttington Shales, Buttington Brickworks, showing the high inclination of the strata against the 'diabase' intrusion at Cefn and the effect of soil-creep at the surface. (See p. 436.)

Plate XXXV.

Fig. 1. Grit-band in the calcareous beds of the Upper Gaerfawr Grits, showing fragments of felspar and of fine-grained basic igneous rock. Magnified 50 diameters. (See p. 428.)

2. The Welshpool Dyke, showing columnar structure in concentric layers. (See p. 447.)

Plate XXXVI.

Figs. 1 & 2. *Trinucleus intermedius*, sp. nov. Natural size. (See p. 449.)

Fig. 3. *Dionide* sp. Magnified 2 diameters. (See p. 450.)

4. *Primitiella unicornis* Ulrich, var. 1. Left valve. Magnified about 16 diameters. (See p. 452.)

5. *Pr. unicornis*, var. 2. Right valve. Magnified about 16 diameters. (See p. 452.)

6. *Ctenobolina* cf. *ciliata* Emmons. Right valve. Magnified about 16 diameters. (See p. 452.)

Figs. 7, 8, & 9. *Cyclonema donaldi*, sp. nov. Natural size. (See p. 453.)

Figs. 10, 11, & 12. *Bellerophon (Protowarthia) portlocki*, sp. nov. Natural size. (See p. 453.)

13 & 14. *Carinaropsis acuta* Ulrich & Scofield. Adult. Natural size. (See p. 454.)

Fig. 15. *C. acuta*. Young specimen. Natural size. (See p. 454.)

16. *Eccyliomphalus contiguus* Ulr., var. *cambrensis*, nov. Natural size. (See p. 454.)

17. *Cyrtolites parvus* Ulr., var. *carinatus*, nov. Natural size. (See p. 455.)

Figs. 18 & 19. *Lingula obtusiformis*, sp. nov. Natural size. (See p. 455.)

20 & 21. *Streptelasma (?)* aff. *breve* Ulr. Natural size. (See p. 455.)

Discussion.

Mr. W. G. Fearnsides congratulated the Author upon his lucid exposition of the rock-succession and structure of a most fascinating district, and upon the great advance of knowledge which was represented by his results. He thought the evidence of the continued instability of the Welshpool anticline during the Silurian Period most important. It showed that the Welshpool district was already unstable, even before depression had allowed Silurian sediments to overlap on to the Longmynd and Carneddau anticlinal districts, and that in later (Wenlock and Ludlow) times it had followed rather accurately the up-and-down movements of those neighbouring districts.

In regard to the Author's correlation of his highest Ordovician subdivision with the Ashgillian of Dr. Marr, the speaker was less satisfied. The terms in which the Author had described the lithological succession from the Trilobite-Dingle Group upwards might well be used to describe the successive members of the Bala Group, either in the region south of Bala Lake or in Western Carnarvonshire; but, in both those districts, the place of the black shales of the Gwern-y-brain Group was taken by equally black shales containing *Diplograptus truncatus*, a graptolite which marked a horizon well below that at which the great Ashgillian Series was supposed to begin. In the opinion of the speaker the Ashgillian Series about Welshpool must be completely overstepped by the sandy and conglomeratic beds of the Llandovery.

Mr. H. H. Thomas congratulated the Author, both on his choice of ground, and on the results that he had achieved. He remarked that the Trilobite-Dingle Beds, from the abundance of *Amplexograptus perexcavatus*, represented a low horizon in the *Dicranograptus* Shales, and should be succeeded by beds containing abundant *Mesograptus* and species of the larger Diplograptids—such as *Orthograptus calcaratus* var. *vulgatus*. He asked whether the Author considered his Pwll-y-glo Beds to be the equivalents of the higher portion of the *Dicranograptus* Shales, as developed in other districts. With regard to the black shales above the Gaerfawr Beds, the speaker agreed with Mr. Fearnsides that there were difficulties in the way of accepting them as belonging to the Ashgillian. He also asked whether it were not possible for these shales to belong to the zone of *Pleurograptus linearis*, and to represent similar shales which in South Wales and elsewhere were characterized by *Diplograptus truncatus*, and occurred beneath the Ashgillian.

He was much impressed by the striking manner in which the undoubted Llandovery beds transgressed the older series, and also by the way in which high zones of the Wenlock came to rest upon rocks of Valentian age. Mr. Cantrill and the speaker had in South Wales also noted that near Llandeilo a high zone of the Wenlock characterized by *Monograptus flemingi* was only a little way above

beds yielding *Pentamerus undatus*. This would indicate an overstep at about the same horizon as in the cases described by the Author.

The PRESIDENT pointed out that the Author's map, when compared with that of the Geological Survey and with Murchison's work in the area, showed how much new work had been done by the Author in this district. He recalled that the previous investigator of the area was Mr. Bickerton Morgan, who unfortunately died before he could complete his work. The district was interesting as a link between the little-known region of South Wales on the one hand, and that of Shropshire on the other. He did not recognize any marked resemblance between the igneous rock described by the Author, and the intrusive or interbedded rocks of the Breidden Hills.

The AUTHOR said, in reply to Mr. Fearnsides, that the difficulty raised with regard to the Black Shales of Gwern-y-brain seemed to depend upon the identification of the graptolites. The horizon of these shales was certainly higher than that suggested. The combined palæontological evidence tended to confirm that view. It was quite possible that zones representative both of the Ashgillian and of the Lower Valentian were present; but, since the beds were very limited both in thickness and in distribution, and since the overlying conglomerate formed the natural base of the Silurian rocks over the rest of the area, the Author had considered the series as one group, which he regarded as corresponding most closely with the Ashgillian.

In reply to Mr. Thomas, he said that the Pwll-y-glo Beds contained *Orthograptus calcaratus* and allied forms, and therefore could be correlated very well with the zones of the *Dicranograptus* Shales of South Wales mentioned by that speaker.

In reply to the President, the Author said that he had in mind the diabases of the Breidden district, and although he did not claim that the Welshpool-Dyke rock was exactly similar to those diabases, it seemed possible that it was a local variation in which the ferromagnesian mineral was not well developed.

In conclusion, he thanked the Fellows present for their kind reception of the paper.

ADMISSION AND PRIVILEGES

OF

FELLOWS OF THE GEOLOGICAL SOCIETY OF LONDON.

EVERY Candidate for admission as a Fellow must be proposed by three or more Fellows, who must sign a Certificate in his favour. The Proposer whose name stands first upon the Certificate must have a personal knowledge of the Candidate.

Fellows on election pay an Admission Fee of Six Guineas. The Annual Contribution paid by Fellows is Two Guineas, due on the 1st of January in every year, and payable in advance; but Fellows elected in November or December pay no Contribution for the current year. The Annual Contribution may, at any time, be compounded for by a payment of Thirty-Five Pounds.

The Fellows are entitled to receive gratuitously all the volumes or parts of volumes of the Quarterly Journal of the Society that may be published after their election, so long as their Annual Contributions are paid; and they may purchase any of the publications of the Society at a reduction of 25 per cent. under the selling-prices.

The Library is open daily to the Fellows between the hours of 10 and 5 (**except during the fortnight commencing on the first Monday in September**; see also next page), and on Meeting-Days until 8 P.M. Under certain restrictions, Fellows are allowed to borrow books from the Library.

Publications to be had of the Geological Society, Burlington House.

QUARTERLY JOURNAL. (Vols. III to LXVI, inclusive.)

Price to Fellows, 13*s.* 6*d.* each (Vols. XV, XXIII, XXX, and XXXIV to LXVI, 16*s.* 6*d.*), in cloth.

GENERAL INDEX TO THE FIRST FIFTY VOLUMES OF THE QUARTERLY JOURNAL (1845–1894). Part I (A–La). Part II (La–Z). Price 5*s.* each. To Fellows 3*s.* 9*d.* each. [Postage 3*d.*]

GEOLOGICAL LITERATURE added to the Geological Society's Library during the years ended December 31st, 1894–1909. Price 2*s.* each. To Fellows, 1*s.* 6*d.* each. [Postage 3*d.*]

THE HISTORY OF THE GEOLOGICAL SOCIETY OF LONDON, by H. B. WOODWARD, F.R.S. Price 7*s.* 6*d.* To Fellows, 6*s.* [Postage 6*d.*]

THE CENTENARY OF THE GEOLOGICAL SOCIETY OF LONDON, recorded by W. W. WATTS, F.R.S. Price 2*s.* net. [Postage 3*d.*]

HUTTON'S 'THEORY OF THE EARTH,' Vol. III., edited by Sir ARCHIBALD GEIKIE, D.C.L., F.R.S. Price 3*s.* 6*d.* To Fellows, 2*s.* [Postage 4*d.*]

THE GEOLOGY OF NEW ZEALAND. Translated by Dr. C. F. FISCHER from the works of MM. HOCHSTETTER & PETERMANN. With an Atlas of Six Maps. Fellows may purchase one Copy of this Book at 2*s.* Additional Copies will be charged 4*s.* [Postage 5*d.*]

CONTENTS.

PAPERS READ.

[No. 268 of the Quarterly Journal will be published next November.]

[The Editor of the Quarterly Journal is directed to make it known to the Public that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

⁂ The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

The Library and Museum at the Apartments of the Society are open every Weekday from Ten o'clock until Five, **except during the fortnight commencing on the first Monday in September, when the Library is closed for the purpose of cleaning; the Library is also closed on Saturdays at One p.m. during the months of August and September.** It is open until Eight P.M. on the Days of Meeting for the loan of books, and from Eight P.M. until the close of each Meeting for conversational purposes only.

Vol. LXVII. NOVEMBER, 1911. **No. 268.**
PART 4.

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY.

EDITED BY

THE ASSISTANT-SECRETARY.

[With Fifteen Plates and One Folding Table, illustrating Papers by Prof. W. S. Boulton, Mr. E. E. L. Dixon & Dr. A. Vaughan, Prof. J. W. Gregory, Mr. R. B. Newton, Mr. R. J. L. Guppy, and Mr. R. H. Rastall.]

LONDON:

LONGMANS, GREEN, AND CO.

PARIS:—CHARLES KLINCKSIECK, 11 RUE DE LILLE.

SOLD ALSO AT THE APARTMENTS OF THE SOCIETY.

Price Five Shillings.

[Issued January 10th, 1912.]

LIST OF THE OFFICERS AND COUNCIL OF THE GEOLOGICAL SOCIETY OF LONDON.

Elected February 17th, 1911.

President.

Prof. William Whitehead Watts, Sc.D., LL.D., M.Sc., F.R.S.

Vice-Presidents.

Charles William Andrews, B.A., D.Sc., F.R.S.
Alfred Harker, M.A., F.R.S.
John Edward Marr, Sc.D., F.R.S.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.

Secretaries.

Prof. Edmund Johnston Garwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S.

Foreign Secretary.

Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.

Treasurer.

Aubrey Strahan, Sc.D., F.R.S.

COUNCIL.

Henry A. Allen.
Tempest Anderson, M.D., D.Sc.
Charles William Andrews, B.A., D.Sc., F.R.S.
Henry Howe Arnold-Bemrose, J.P., Sc.D.
George Barrow.
Prof. Thomas George Bonney, Sc.D., LL.D., F.R.S.
Prof. William S. Boulton, B.Sc.
James Vincent Elsden, D.Sc.
John Smith Flett, M.A., D.Sc.
Prof. Edmund Johnston Garwood, M.A.
Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.
Alfred Harker, M.A., F.R.S.
Robert Stansfield Herries, M.A.
Bedford McNeill, Assoc.R.S.M.
John Edward Marr, Sc.D., F.R.S.
George Thurland Prior, M.A., D.Sc.
Prof. Sidney Hugh Reynolds, M.A.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.
Aubrey Strahan, Sc.D., F.R.S.
Herbert Henry Thomas, M.A., B.Sc.
Prof. William Whitehead Watts, Sc.D., LL.D., M.Sc., F.R.S.
Rev. Henry Hoyte Winwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

Assistant-Secretary, Clerk, Librarian, and Curator.

L. L. Belinfante, M.Sc.

Assistants in Office, Library, and Museum.

W. Rupert Jones. Clyde H. Black.
Arthur Greig.

STANDING PUBLICATION COMMITTEE.

Prof. W. W. Watts, *President*.

Prof. E. J. Garwood, } *Secretaries.*
Dr. A. Smith Woodward, }

Mr. H. A. Allen.
Dr. C. W. Andrews.
Dr. J. V. Elsden.
Dr. J. S. Flett.
Mr. A. Harker.
Mr. R. S. Herries.
Dr. J. E. Marr.
Dr. G. T. Prior.
Prof. S. H. Reynolds.
Prof. W. J. Sollas.
Dr. A. Strahan.
Mr. H. H. Thomas.

EVENING MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

Session 1911–1912.

1912.

Wednesday,	January	24*
„	February (*Anniversary*, Friday, Feb. 16th)	7*—28*
„	March	13*—27
„	April	17*
„	May	1—15*
„	June	5—19*

[*Business will commence at Eight o'Clock precisely.*]

The asterisks denote the dates on which the Council will meet.

beds yielding *Pentamerus undatus*. This would indicate an overstep at about the same horizon as in the cases described by the Author.

The PRESIDENT (Prof. WATTS) pointed out that the Author's map, when compared with that of the Geological Survey and with Murchison's work in the area, showed how much new work had been done by the Author in this district. He recalled that the previous investigator of the area was Mr. Bickerton Morgan, who unfortunately died before he could complete his work. The district was interesting as a link between the little-known region of South Wales on the one hand, and that of Shropshire on the other. He did not recognize any marked resemblance between the igneous rock described by the Author, and the intrusive or interbedded rocks of the Breidden Hills.

The AUTHOR said, in reply to Mr. Fearnsides, that the difficulty raised with regard to the Black Shales of Gwern-y-brain seemed to depend upon the identification of the graptolites. The horizon of these shales was certainly higher than that suggested. The combined palæontological evidence tended to confirm that view. It was quite possible that zones representative both of the Ashgillian and of the Lower Valentian were present; but, since the beds were very limited both in thickness and in distribution, and since the overlying conglomerate formed the natural base of the Silurian rocks over the rest of the area, the Author had considered the series as one group, which he regarded as corresponding most closely with the Ashgillian.

In reply to Mr. Thomas, he said that the Pwll-y-glo Beds contained *Orthograptus calcaratus* and allied forms, and therefore could be correlated very well with the zones of the *Dicranograptus* Shales of South Wales mentioned by that speaker.

In reply to the President, the Author said that he had in mind the diabases of the Breidden district, and although he did not claim that the Welshpool-Dyke rock was exactly similar to those diabases, it seemed possible that it was a local variation in which the ferromagnesian mineral was not well developed.

In conclusion, he thanked the Fellows present for their kind reception of the paper.

16. *On a* MONCHIQUITE INTRUSION *in the* OLD RED SANDSTONE *of* MONMOUTHSHIRE. By Prof. WILLIAM S. BOULTON, B.Sc., Assoc. R.C.S., F.G.S. (Read June 14th, 1911.)

[PLATE XXXVII—MICROSCOPE-SECTIONS.]

CONTENTS.

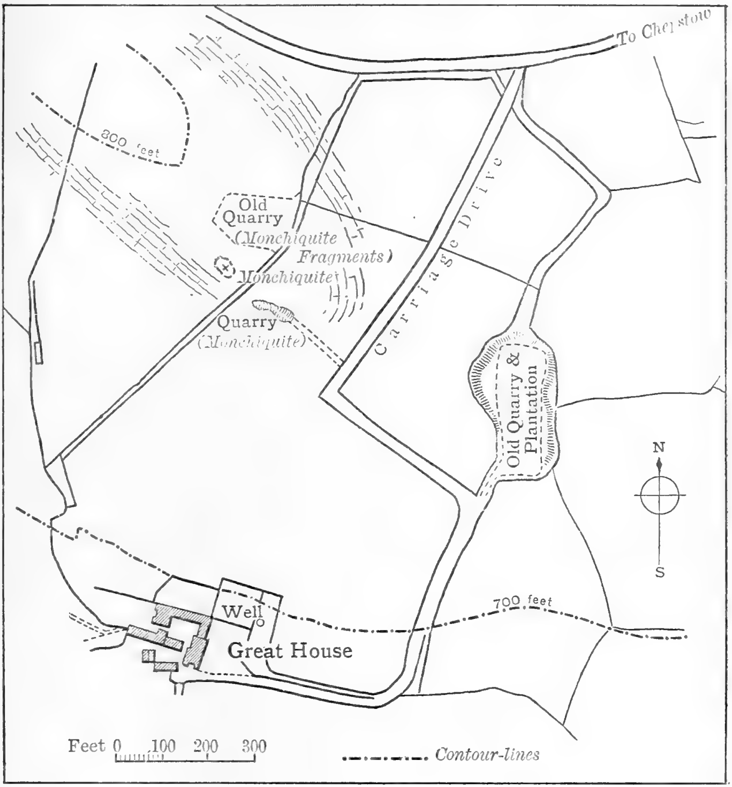
I. POSITION AND FIELD-RELATIONS.

THE igneous intrusion here described, and hitherto unrecorded, is situated in Monmouthshire in lat. 51° 40′ N., long. 2° 49′ 30″ W. Following the main road from Chepstow to Usk for about 7½ miles, and then branching off southwards for another mile and a half, we come to a place which is marked on the 6-inch Ordnance map of the district as the 'Great House'; and about 250 yards north of it, the rocks in question are exposed. Some 70 yards north-west of the carriage-drive leading to the house (where I first noticed the rock which was being used to 'metal' the drive), a small quarry has been excavated in the rising ground. It is in this quarry that the main exposure of the monchiquite is seen, and from which most of the material described in this paper was obtained. (Fig. 1, p. 461.)

The quarry measures about 20 by 25 yards and is some 20 feet deep. A few yards west of it is a small, shallow opening, from which the igneous rock has evidently been taken, and some of it may still be seen *in situ* cropping out through the grass. Still farther west, over the fence, a similar hollow is seen, and a little north of it is an old quarry measuring 20 yards across and of considerable depth, with a pool at the bottom and the sides overgrown with bushes and long grass. In this old disused quarry no rock is visible in position; but large, loose lumps of the monchiquite and slabs of sandstone are lying about.

The monchiquite is intrusive in the Old Red Sandstone, which covers so large an area in this part of Monmouthshire, though the exact stratigraphical position is uncertain. From general traverses through the district, it appears to lie near the base of the upper division of the system or Brownstones, made up of red sandstones and conglomerates, with subordinate bands of red marl.

Fig. 1.—*Map of the neighbourhood of the Great House, Golden Hill (Monmouthshire).*



II. Field-Characters and Relations to the Contact-Rocks.

The rock in the recently opened quarry[1] is much weathered to a buff or rusty colour for a depth of 6 to 10 feet, and along the joints; but where unweathered it is dark grey, nearly black, compact and glassy looking, and extremely hard and tough. It contains remarkably big phenocrysts of augite and biotite, the former measuring up to 5 or 6 inches in length; and when much corroded, as is often the case, they form spherical or ovoid masses, of a black or dark greenish colour. The biotite-plates up to 2 inches across lie on the face of the quarry, or project conspicuously from the rock.

In the ground-mass, white, green, and pink patches, some small and round, others large and irregular, are evidently filled with secondary products. Here and there are patches of rounded or oval shape, up to 8 or 9 inches across, quite different in appearance

---

[1] I was told by a man on the estate that it was opened about ten years ago.

from the augites. They are made up of a confused aggregate of a brown or green, bronzy looking mineral, with a marked mica-like cleavage; together with a purplish-grey substance that effervesces under acid; small, irregular, black crystalline grains of augite; and much green and yellow colouring-matter. As will be shown later, these are included lumps of olivine-augite rock, distinct from, but related to, the monchiquite in which they occur.

A very noticeable feature is the large amount of the country-rock that has been caught up by the intruded magma. Chips of sandstone and bigger lumps, upwards of 2 feet across, both of sandstones and marl, are irregularly distributed—in one part of the mass so thickly as to suggest a tuff or agglomerate; and on the weathered surface they give to the rock a very rough, rusty looking appearance.

The included lumps of marl are generally well rounded, and have been converted into a dark porcellanite with a sharp flinty fracture; while the subangular lumps of sandstone have a bleached appearance or yellowish-brown colour, and break with a lustrous fracture. Much secondary calcite, silica, and chloritic matter occur in the vicinity of these xenoliths, the silica often assuming an agate-like disposition.

On the northern face of the quarry, particularly in the central part, the rock shows a pronounced spheroidal jointing, with the characteristic weathering into concentric shells.

The principal linear joints run in two directions, one set nearly due north and south, and the other north-west and south-east. Iron-stained silica, with some calcite and chlorite, and a little earthy manganese oxide and copper carbonate fill most of the joints and cracks.

The nature of the intrusion and its relation to the surrounding rocks are difficult to determine. Only at one place is it possible to see a junction of the igneous rock and the sandstones: namely, at the eastern side of the quarry. Here the invading rock cuts obliquely across the sandstones, which are dipping at this spot at about 30° north-eastwards,[1] so that the line of junction is roughly in an east-north-easterly direction.

The monchiquite, which is exposed at the centre of the quarry to a depth of some 6 feet below the level of the sandstone, abuts against the sandstone with a nearly vertical junction-surface, running with the dip. The junction then coincides with the bedding in a sill-like way, for about 12 or 15 yards to the end of the quarry. For some 3 or 4 feet from the junction the igneous rock assumes a less massive appearance; it has a rough, scoriaceous, and finely nodular texture with a coarse pseudo-lamination, the joint-planes lying nearly vertical. In this shaly-looking igneous rock lie rounded lumps of burnt marl, measuring from 6 inches to 3 feet across. They are brown and yellow on the outer burnt border, but dark

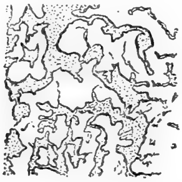
---

[1] The general dip hereabouts is 10° east-north-eastwards.

red, nearly black, inside, and weather into beautifully-regular concentric shells. Some have an internal, finely-nodular structure, breaking up like a perlitic pitchstone, doubtless due to shrinkage after having been heated up in the magma.

Fig. 2, drawn natural size, shows a somewhat striking appearance of the sandstone on the floor of the quarry, close to the contact. On a fractured or polished surface of the rock, deep yellow areas, not unlike the spherulitic patches of an obsidian or felsite, lie on a dark purplish-red ground. A thin slice further shows that, in the yellow areas, the rock is thickly covered with yellow oxide of iron and the quartz-grains are partly or wholly corroded; while in the purple areas the sandstone is practically unaltered, except for strings and occasional patches of magnetite.

Fig. 2.—*Fine-grained Old Red Sandstone at the contact with the monchiquite, showing partial fusion. (Natural size.)*



[Dotted areas are dark purple sandstone. Light areas are deeply stained with yellow limonite, and the quartz-grains are in part or wholly corroded.]

An examination of this contact, together with the disposition of the included fragments of sandstone at the western end of the quarry, suggests that the magma forced its way upwards, or perhaps obliquely upwards from the north-west, and then ran for some distance eastwards more or less with the bedding of the sandstones. It may then have passed upwards into strata since removed by denudation.

It will be gathered from the foregoing observations that it is not possible to define positively the boundary-walls of the intrusion, except on this eastern side; and here the junction is irregular. A reference to the sketch-map (fig. 1, p. 461) shows the small openings immediately to the west of the quarry, in one of which the igneous rock is exposed; and the old, overgrown quarry, where loose blocks of the monchiquite have been left.[1] The old quarry and plantation, 200 yards south-east of the recently worked quarry, shows no trace of igneous rock; it is only about 8 to 10 feet deep, and was apparently opened up in the sandstones. Thus we may take it as practically certain that the monchiquite crops out for a distance of about 300 feet in a north-north-westerly direction, and for about 200 feet in a direction at right angles to that.

All these openings where the monchiquite is exposed lie on a rounded crest, which, beginning abruptly near the eastern quarry, runs for nearly half a mile in a north-westerly direction across Golden Hill. The trend of the intrusion may be in this north-westerly

---

[1] No record of the working of this quarry could be obtained.

direction, and it may be a dyke of considerable width, which ends abruptly at the south-eastern end where the quarry has been lately worked; and, after for a time traversing the sandstones roughly parallel with the bedding, the magma may have passed upwards into strata now removed. No trace of the igneous rock, however, either in outcrop or in surface-fragments, could be seen along this crest, west of the old quarry already mentioned.

If the junction of the monchiquite and sandstone at the eastern end of the recent quarry is to be regarded as one of the walls of a dyke, then the dyke would trend east-north-eastwards, which is the direction of the Bartestree dyke, near Hereford (mentioned on p. 474). But if so, it would be of great thickness, between 200 and 300 feet; and moreover, the form of the ground, which is probably determined to a great extent by the very hard igneous rock, is against the dyke having this direction.

The plentiful inclusion of xenoliths of the country-rock is not inconsistent with the view that the monchiquite is a dyke or a sill[1]; but, having regard to the shape of the known outcrop, it seems not unreasonable to conclude that we have here a volcanic plug or bysmalith[2] with an irregular sill-like extension in an easterly direction.

The available evidence, however, is by no means conclusive, and the exact nature of the intrusion must be regarded for the present as doubtful.

III. Petrographical Details.

Owing to the extent to which the rock has been weathered, and to the fact that the quarry is not being worked at the present time, big fresh lumps are difficult to obtain. Then, too, the included Old-Red-Sandstone fragments are very plentiful in places; and, as will be shown later, the monchiquite has an abnormal development of carbonate and other secondary products in their vicinity.

Where the rock is coarsely porphyritic, as in the central parts of the quarry, the large augite and biotite-crystals arrest attention.

Augite.—Perhaps the most striking feature of the rock is the unusual development of the augite-phenocrysts. An individual crystal was measured, having a length of 6 inches and breadth of 3 inches, while prisms 3 or 4 inches long are quite common.[3] Occasionally they have their original crystalline form in part well defined, but usually the crystals have suffered much corrosion, and many are quite spherical or ovoid in shape with no trace of their original form, and in not a few cases they are deeply embayed by the matrix, or almost entirely resorbed.

---

[1] See A. Harker, 'The Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. 1904, chap. xx.

[2] J. P. Iddings, 'Igneous Rocks' vol. i (1909) p. 315.

[3] No evidence is forthcoming that these large augite-phenocrysts are aggregates, producing a glomeroporphyritic structure; in all cases they appear to be single crystals. They are, again, easily distinguished in the field, and under the microscope, from the xenoliths of picrite described on p. 471.

The mineral is typically black, sometimes greenish, with a dull pitchy lustre and conchoidal fracture. The crystals that have suffered corrosion to the greatest extent seem to be those which exhibit a specially dull lustre, while smaller ones have the more usual augitic lustre.

It is much cracked, with limonite, chlorite, and secondary carbonate along the cracks. This strong tendency to crack makes it practically impossible to break off specimens of the rock with very big augite-phenocrysts entire. The crystals that have been much corroded break away from the enveloping rock very readily, evidently because the zone of fused and recrystallized augite (see below) that surrounds the inner core makes a weak contact with the matrix.

Seen in thin section the mineral is pale green, nearly colourless, occasionally a very pale pinkish-brown. In thicker sections the colour is olive-green with slight pleochroism, the colours varying from pale olive-green to brownish green. Besides showing the usual prismatic partings, the mineral is much cracked, a yellowish-green substance filling most of the cracks. Small rounded crystals of altered olivine sometimes occur pœcilitically; but, apart from these, and rods and flakes of hæmatite, the crystals show remarkably few inclusions. No cases of twinning were met with.

It is probably a chrome-diopside, a variety of augite common in rocks of this class. Generally, the borders show an outer zone of resorbed augite, with a faint granular polarization; and, in many instances, this border has been supplemented by an outer zone of fresh augite that crystallized out from the magma immediately after the corrosion of the phenocryst. This outermost zone is purplish brown, appreciably pleochroic, and quite distinct in colour from the original crystal. It is generally made up of minute stout prisms, oriented with the principal axis of the phenocryst, so that they all extinguish together, and uniformly with the original inner core. (See Pl. XXXVII, fig. 1.)

Biotite.—Phenocrysts of biotite measuring as much as 2 inches across are plentiful in some parts of the rock, and they sometimes exhibit a parallel arrangement. They are in six-sided plates, but usually the angles have been worn off by corrosion, so that they are circular or oval.

By transmitted light they show a deep colour, with strong pleochroism, the colour varying from yellow to reddish brown. Examples can be noted where the crystal is deeply embayed by the matrix, or again, where the crystal has been almost entirely eaten up by the magma. Many of the crystals are bent and frayed out at the edges, indicating violent movement and friction since their formation.

Olivine.—Idiomorphic olivine-crystals, now entirely replaced by serpentine, carbonates, etc., are corroded in much the same way as the augite and biotite. It is probable, however, that some

of these corroded olivine-phenocrysts represent portions of the plutonic xenoliths or 'nodules' which contain abundant olivine (see p. 471).

The ground-mass enclosing these large phenocrysts contains smaller porphyritic crystals of a second generation, including augite and olivine, with occasional biotite, together with chromite and rounded quartz-crystals, all set in a fine matrix which, under a high power, resolves itself into analcite, embedded in which are minute prisms of augite, plentiful octahedra of iron-ore, scales of biotite and minute needles of apatite; while secondary products, such as carbonates, idiomorphic analcite and other zeolites, chlorite, hæmatite, and limonite are locally abundant, especially in the ocelli and steam-cavities.

The porphyritic augites of the second generation, ranging in length from 1 mm. down to the minute prisms of the ground-mass, are well-formed, idiomorphic or sub-idiomorphic crystals, with their angles perfectly sharp, and presenting the usual octagonal and prismatic sections. The colour is purplish brown, with slight pleochroism. Twinning is rare. Purplish-brown crystals can be seen with a nucleus of nearly colourless and partly-decomposed augite, that doubtless represents the last remnant of the resorbed larger phenocryst, on which the later augite has crystallized out in optical continuity. It sometimes surrounds altered olivine, and very often encloses crystals of biotite. Crystals occur with the centre pale in colour and decomposed, surrounded by brown augite enclosing in a zonal manner numerous flakes of biotite.

Olivine of the second generation occurs in small idiomorphic crystals (averaging 0·3 mm. in length), showing the typical bipyramidal forms and cleavage-cracks, but now entirely represented by pseudomorphs of serpentine, iron-oxide, calcite, and colourless zeolites.

The chromite or picotite varies in colour from deep reddish-brown to brownish-yellow. It is usually in rounded crystals where embedded in the matrix, their outlines being often emphasized by broad, irregular, black borders of iron-ore.

The biotite closely resembles the earlier phenocrysts.

The quartz-grains are perfectly clear, except for the usual minute, linear inclusions. They invariably show rounded outlines, and are often considerably embayed by the ground-mass, with a yellow or dark corrosion-border of fine granular substance surrounding them (fig. 3 D, p. 467). In these characters they resemble the quartz-inclusions or xenocrysts in other well-known basic lamprophyres that have been described.[1]

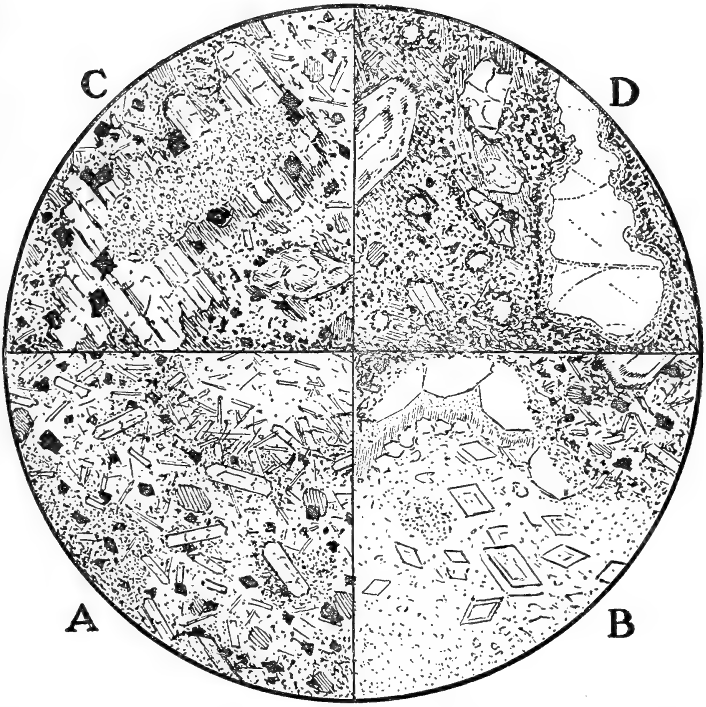
The ground-mass under a low power is typically brown or dark grey, plentifully dusted over with minute magnetite-grains. But a high power reveals a very interesting structure, which throws considerable light on the composition and affinities of the rock.

---

[1] See A. Harker, Geol. Mag. dec. iii, vol. ix (1892) pp. 199–206 & 485–88.

Minute augite-prisms (of the third generation) with an average length of 0·05 mm. and breadth of 0·01 mm., nearly colourless, or of a pale greyish-purple or purplish-brown, and showing longitudinal striation and faint cross-parting, are abundant. Minute scales and plates of deep reddish-brown biotite often cling to the octahedra of iron-ore; and, filling up the spaces between all these crystals, is a colourless or pale yellowish-grey or cloudy substance, usually isotropic, but in places faintly birefringent with pale neutral tints, and enclosing very minute needles of apatite. Its low refractive index, absence of colour, and isotropic character suggest the mineral analcite, probably as a primary constituent, and evidence will shortly appear which strengthens this view (fig. 3 A, above).

Fig. 3.



[A = Analcite ground-mass, enclosing augite-prisms, apatite-needles, iron-ore, and biotite. Towards the centre is a clearer space occupied by allotriomorphic analcite. × 240 diameters.

B = Part of ocellus or steam-cavity, with sub-idiomorphic analcite, carbonate-rhombs, and pale-green chlorite. × 240 diameters.

C = Decomposed augite-phenocryst, overgrown by augite-prisms. × 100 diameters.

D = Corroded quartz, together with olivine- and augite-crystals, in a monchiquite ground-mass. × 40 diameters.]

A close search has failed to reveal any undoubted nepheline in this ground-mass, but a fibrous, colourless, faintly-birefringent zeolite, generally occurring in radial aggregates, and possessing a low refraction, is probably the mineral natrolite, and may possibly result from the decomposition of nepheline.

Ocellar spaces are frequently present, some quite small, circular or elongated, with a parallel arrangement, doubtless representing original vesicles. Others are much bigger and more irregular, suggestive of drusy cavities. They are now filled with pale-green chloritic matter; carbonates, often in beautifully sharp rhombs with marked zonal structure; and perfectly clear and colourless, idiomorphic or sub-idiomorphic and isotropic crystals of secondary[1] analcite (fig. 3 B, p. 467).

Very minute, colourless or yellowish needles in feathery bunches can also be made out, which usually polarize in bright tints. These have proved too small for exact determination; they may be muscovite or a mineral of the zeolite group.

Many of the spaces show a zonal arrangement, most frequently with the pale-green chloritic substance occupying the centre of the space and enclosing the carbonate rhombs; while the analcite-crystals and the fibrous substance line the walls of the cavity (fig. 3 B).

Some, again, have very indefinite outlines. They are merely clearer spaces merging gradually into the surrounding ground-mass. In such cases the clear space is occupied by allotriomorphic analcite, and perhaps some carbonate and chlorite, while small biotite-needles and augite-prisms with octahedra of magnetite range themselves peripherally, projecting some distance into the clear space (fig. 3 A).

The small ocelli pass by gradual stages into the larger pale pink and white patches so noticeable in the hand-specimen, including those which have banded agate-like or mammillated structure, and where the infilling material is often iron-stained chalcedonic silica.

Some of the rock-sections reveal special points of interest. Slide M 401 may be taken as an example (Pl. XXXVII, fig. 4). It shows a small xenolith of fine-grained sandstone about half an inch across, and surrounding it are numerous glassy fragments of the igneous rock, showing a striking resemblance to palagonite-tuff. The lapilli consist of the usual brown or yellowish-red basic glass, enclosing small, perfectly spherical vesicles, now occupied by zeolites; while minute prisms of augite, olivine, and grains of quartz are also embedded in this glass. These fragments are set in a pale-grey or colourless matrix made up of abundant rhombs of carbonate, zeolites, and small fragments of sandstone.

The glassy character of these lapilli is doubtless to be explained

---

[1] The term secondary is here used without implying any considerable interval between the formation of the analcite of the ground-mass and that of the ocelli.

by the rapid cooling of the magma, separated by the explosive violence of the intrusion into small fragments, mixed confusedly with cold chips of the adjacent sandstone.[1] It is clear that the fragmental character of the rock, both igneous and enclosed sedimentary, testifies to the violence of the intrusion; but an added interest is the significant difference between this glassy variety of the magma and the usual (analcite) matrix, already described. In other parts of the rock, small areas of glass with a very dark-brown colour by transmitted light, can be made out. But, in every case noted, the glassy patch surrounds or partly fringes a xenolith, and is sharply separated off from the normal analcite-matrix (Pl. XXXVII, fig. 5); or, if the glass occurs in somewhat larger patches, it is invariably filled with innumerable small xenoliths. The fact that we have, side by side as it were, the brown and yellow basic glass and the colourless isotropic substance which ordinarily plays the part of ground-mass in this rock, affords additional evidence that this colourless substance is not glass, but analcite.[2]

As to whether the analcite of the ground-mass is primary, that is, pyrogenetic, it is to be observed that, unlike some other rocks of this class containing analcite, the constituents of this Monmouthshire monchiquite are not all of them fresh; the olivine in particular is decomposed, and there is much secondary carbonate in the rock (see Analysis I, p. 470). On the other hand, the boundary between the analcite and the locally-developed glass described above is invariably a sharp one, not in the least suggestive of the conversion of glass into analcite; and, moreover, the mineral of the ground-mass is interstitial and without crystal-outlines, unlike the secondary analcite of the ocelli. Having regard to these points and to the analogy of other analcite-bearing rocks where the mineral plays the part of ground-mass as in this rock, and where the other minerals are quite fresh, it seems highly probable that the analcite here is primary.

The magma was apparently very hydrous, and crystallized under pressure and somewhat rapidly, after being violently intruded in a dyke-like or plug-like form into the comparatively cold surrounding rocks. Analcite was formed as a sparse ground-mass between the already consolidated minerals, showing here and there in more conspicuous patches, comparatively free from ferromagnesian minerals and iron-ore ('analcite-phenocrysts' of Pirsson). But, where locally and accidentally there was sudden relief of pressure and shattering of the magma, accompanied by rapid chilling, as near the small xenoliths of sandstone and marl, the characteristic basic glass of the limburgites, full of minute vesicles, resulted instead of analcite.

---

[1] The possibility of the local absorption by the magma of silica, etc., from the xenoliths must be taken into account; but it seems more probable that the operative cause in the formation of the glass was the one stated.

[2] The finely powdered rock, when digested with very dilute (5 per cent.) hydrochloric acid, yields gelatinous silica.

IV. Chemical Composition.

An analysis of the rock[1] has been made by Mr. Sydney J. Johnstone, of the Imperial Institute. It is given below, with some others for comparison :—

	I.	II.	III.	IV.	V.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	40·26	39·54	42·22	44·01	42·46
TiO_2	2·26	2·72	2·49	2·03	2·47
Al_2O_3	10·22	13·74	10·62	12·32	12·04
FeO	7·14	7·85	6·18	8·75	5·34
Fe_2O_3	2·86	4·05	4·74	3·62	3·19
Cr_2O_3	trace	...	0·10	trace	...
V_2O_3	...	...	0·05	...	...
MnO	0·20	0·40	0·50	0·21	0·16
(CoNi)O	...	0·05	0·05	trace	...
BaO	...	0·19	0·04	...	undet.
CaO	13·43	9·64	14·80	10·57	12·14
MgO	8·75	8·66	8·68	12·86	12·40
K_2O	1·32	3·70	1·41	0·49	2·68
Na_2O	1·51	2·24	2·46	1·68	1·21
P_2O_5	0·65	1·01	0·73	0·17	0·84
SO_3	0·62	...	...	...	none
S	...	...	0·12	0·11	...
FeS_2	...	0·27	...	...	...
CO_2	5·80	2·48	3·57	trace	0·55
Cl	trace	...	...	...	none
H_2O at 105° C.	1·24	0·61	0·50	0·89	4·03
H_2O above 105° C.	3·53	2·77	1·16	2·73	
Totals	99·79	99·92	100·42	100·44	99·51

I = Monchiquite near 'Great House,' Golden Hill, Monmouthshire. (Anal. S. J. Johnstone.)

II = Nepheline-ouachitite, Kilchattan, Colonsay. (Anal. E. G. Radley.) 'The Geology of Colonsay & Oronsay, with part of the Ross of Mull' Mem. Geol. Surv. Scot. 1911, p. 46.

III = Camptonite, Sailean Sligenach, Ardmucknish, Argyllshire. (Anal. E. G. Radley.) See 'The Geology of the Country near Oban & Dalmally' Mem. Geol. Surv. Scot. 1908, p. 126.

IV = Olivine-dolerite, Ciche na Beinne Deirge, Skye. (Anal. W. Pollard.) See 'The Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. 1904, p. 325; also 'Geol. of Colonsay, &c.' *op. supra cit.* p. 46.

V = Monchiquite, Willow Creek, Castle Mountain district, Montana (Weed & Pirsson, Bull. U.S. Geol. Surv. No. 139, 1896, p. 115). (Anal. L. V. Pirsson.)

The specific gravity of the Monmouthshire rock is 2·85. It has

---

[1] In selecting material for the analysis, care was taken to exclude, as far as possible, xenoliths of Old Red Sandstone and picrite. As shown on p. 473, fragments of the latter would not appreciably affect the result; while the former, if present, would have the effect of slightly raising the percentage of silica and alumina.

a low percentage of silica [1] and alumina, and a high percentage of lime, magnesia, and iron, while the alkalies are only moderate in amount. Thus the composition is that of a typical basic lamprophyre, which is fully borne out by the petrographical characters already described.

The presence of phenocrysts of augite, biotite, and olivine, the abundance of augite-prisms and biotite-flakes in the matrix, the absence of felspars, and the presence of analcite as a colourless isotropic base, mark it out as a monchiquite.[2]

That the gap between the monchiquite and the limburgite types is not considerable would appear probable, seeing that both occur in close juxtaposition as variations of the same rock; not, however, by a change of the basic glass into analcite, but by the practically simultaneous formation of glass and analcite under somewhat different conditions, apparently in the main a different rate of cooling.

An unusual amount of carbon dioxide appears in the analysis, and this was to be expected in view of the great development of carbonate revealed by the microscope. Some of this carbonate may possibly be in the form of dolomite, but most of it is calcite. The finely-powdered rock, and the ocelli in hand-specimens, effervesce vigorously with very dilute hydrochloric acid. Thus, in comparing the composition of this rock with that of others showing less carbon dioxide, it will be necessary to make some deduction from the lime-content.[3] The soda is rather smaller in amount than anticipated, and less than in most rocks that have been described as monchiquites.[4] The alkalies of the monchiquite group vary greatly in amount; in nearly all cases the soda is in excess of the potash.

V. THE OLIVINE-AUGITE-ROCK INCLUSIONS.

We will now consider the inclusions or 'nodules' of somewhat coarsely-crystalline rock, which contain the conspicuous, bronzy, mica-like substance, and are obviously quite distinct from the phenocrysts of augite and biotite, as well as from the xenoliths of Old Red Sandstone.

Seen under the microscope, the junction of one of these inclusions and the containing rock shows clearly a corrosion-border of faintly-polarizing granular material with much iron-oxide; and the

---

[1] Three additional determinations of silica were made of three different specimens of the rock in the laboratory of University College, Cardiff. The results were 40·75, 41·04, and 42·53 per cent. respectively.

[2] The term monchiquite as here used is in the sense advocated by L. V. Pirsson, who showed that the 'pitchstone-glass' of the original monchiquite of Hunter & Rosenbusch is really analcite (see Journ. Geol. Chicago, vol. iv, 1896, p. 679).

[3] If all the carbon dioxide is combined with lime, and all the calcium carbonate is of extraneous origin, the percentage of lime in the analysis would be reduced to the extent of about 7·4.

[4] The monchiquite from the Castle-Mountain district, Montana (see Analysis V, p. 470), contains only 1·21 per cent. of soda.

monchiquite near the contact usually shows the dark-brown, glassy matrix already described as characteristic of the vicinity of xenoliths.

Allotriomorphic crystals of olivine make up perhaps the bulk of the rock, showing the characteristic cracks, but with none of the original mineral left. In its place is a colourless or grey substance (carbonate)[1] with fibres and scales of serpentine and iron-oxide. Beautiful examples of stellate and dendritic growths of magnetite occur.[2]

Associated with the olivine is the mica-like mineral, which is so conspicuous in hand-specimens of the nodules. Macroscopically, it is dark green or brown, often with a pronounced schiller or bronzy lustre, and a strong cleavage, so that it can be peeled off by a knife into flakes which are very soft and brittle, and easily crush into a greenish-yellow powder.

Thin sections are yellow and green or pale reddish-brown by transmitted light, in nearly all cases distinctly pleochroic, the colour being green or bluish-green for vibrations parallel to the short axis of the polarizer, and yellowish for vibrations at right-angles. The cleavage is very marked, and extinction invariably takes place parallel to it. Cleavage-flakes, examined separately, show a variety of colour by transmitted light, from bright yellow to green and brownish-red. A yellowish-green flake, with fine striations and faint granular patches and slight dichroism, gave in convergent polarized light the acute bisectrix of an interference-figure, with a small optic axial angle, and with the optic axial plane disposed parallel to the length of the flake. Another flake, with clusters of very minute yellow-brown granules, showed fine striations along the plane of main cleavage, and between crossed nicols a marked fibrous or rod-like structure, with the fibres polarizing brilliantly, and in separate bundles.

The double refraction is strong, the interference-colours belonging to the second order. In one or two places, the habit and optical properties generally show a striking resemblance to biotite.

The rods, fibres, and lamellæ appear to start from one transverse crack, and extend perpendicularly to the next transverse crack.

There seems to be no doubt that this substance is an alteration-product of the olivine, and it closely resembles the mineral iddingsite, regarded by some mineralogists as a definite variety of serpentine.

It is just possible that bastite-pseudomorphs after a rhombic pyroxene occur in these nodules, for a few patches of the paler variety of the green substance suggest it; but, so far, no satisfactory determination has been made.

Allotriomorphic plates of pale-green augite, often partly or

---

[1] The finely-powdered rock, when treated with very dilute hydrochloric acid, shows, under the microscope, a vigorous reaction in the fragments of this altered olivine.

[2] See J. W. Judd, 'On the Tertiary & Older Peridotites of Scotland' Q. J. G. S. vol. xli (1885) p. 382.

entirely surrounding the olivine, bear an unmistakable resemblance, both in colour and association, to the chrome-diopside of some of the picrites and lherzolites. In places, an approach to the diallagic structure was observed.

Irregular grains and patches of translucent chromite or picotite[1] are plentiful, up to 6 mm. across, usually of a deep yellowish colour, but sometimes yellow-brown, and in one or two small patches they have a deep green colour, possibly indicating pleonaste. A bright yellow-green substance often extends for some distance from the margin of the chromite-grains, and is found also in the cracks of adjacent minerals; it is, presumably, chrome-oxide.

The rock is unquestionably a peridotite, and approaches to a coarsely-crystalline picrite (Pl. XXXVII, fig. 6). The question arises as to how far these corroded xenoliths of picrite are related to the monchiquite. The diopside, olivine, and chromite of the picrite are minerals which occur as phenocrysts in the monchiquite, except that the augite of the picrite has the additional diallagic structure slightly developed, while the olivine tends to pass into the iddingsite product, rather than into the usual serpentine. Moreover, the chemical composition of the picrites agrees very closely with that of our monchiquite. For purposes of comparison, the analysis of a picrite is placed alongside that of the Monmouthshire monchiquite, and the close similarity is at once detected:—

	I.	II.
	Per cent.	Per cent.
SiO_2	40·26	42·85
TiO_2	2·26	...
FeO	7·14	6·86
Fe_2O_3	2·86	6·27
Al_2O_3	10·22	10·42
Cr_2O_3	trace	...
MnO	0·20	...
CaO	13·43	11·84
MgO	8·75	9·01
K_2O	1·32	1·61
Na_2O	1·51	1·65
P_2O_5	0·65	...
SO_3	0·62	...
CO_2	5·80	5·88
H_2O at 105° C	1·24	2·70
H_2O above 105° C.	3·53	
Totals	99·79	99·09

I = Monchiquite near 'Great House,' Golden Hill, Monmouthshire. (Anal. S. J. Johnstone.)

II = Altered picrite from Söhle (see J. J. H. Teall, 'British Petrography 1888, p. 130). This has suffered a change whereby magnesia has been removed and lime introduced. A similar change in composition has been effected in the Monmouthshire monchiquite and its picritic inclusions.

---

[1] The heavy particles were separated from the powdered rock, and gave the chromium-green colour with the borax bead.

The conclusion would appear reasonable, therefore, that the two rocks—the included picrite and the enclosing monchiquite—are nearly related. Unlike the xenoliths of Old Red Sandstone, which are 'accidental,' these picritic nodules must be regarded as 'cognate,'[1] and they probably represent portions of the already consolidated, deep-seated magma from which the monchiquite had its source, portions which were carried upwards by the latter in its violent intrusion into its present position.[2]

VI. AFFINITIES WITH OTHER ROCKS.

When a hand-specimen of the rock, with conspicuous crystals of augite and biotite, was shown to Dr. Flett and Mr. H. H. Thomas, they at once recognized its striking resemblance to some of the basic lamprophyres of Colonsay, recently described by the Officers of the Geological Survey in a memoir now passing through the press. Through the courtesy of the Director and Dr. Flett, I have been able to look over some of the proofs of this memoir, and I have also examined some of the typical rock-specimens and microscope-slides described therein.[3]

Among the minor intrusions of Colonsay, one in particular closely resembles the Monmouthshire rock in many respects. It has the same black, glassy look, with small pink and white ocelli and with large corroded phenocrysts of augite and biotite. There are minor differences: thus the Colonsay rock contains hornblende-phenocrysts and no olivine, and the biotite is more abundant in the ground-mass, while the rock on the whole is somewhat fresher than the Monmouthshire rock. Dr. Flett classes it with the 'ouachitites' of J. F. Williams.[4]

Except for the higher alkalies, it will be seen (p. 470) that this Colonsay rock is very closely allied chemically to the Monmouthshire rock. The associated analcite-bearing dolerites (crinanites) of Colonsay and the camptonites of Argyllshire, especially the Ardmucknish rock, the analysis of which is quoted on p. 470, are also very similar in composition. So, too, are the monchiquites of America, described by Pirsson, Weed, and others: an analysis of one of these American rocks appears in the last column on p. 470.

It becomes important to enquire whether the basic intrusion into the Old Red Sandstone at Bartestree, near Hereford,[5] some 30 miles north-north-east of the Monmouthshire monchiquite, and the only other igneous intrusion in the Old Red Sandstone of the South Wales area, is in any way related to the rock which we are now considering. Unfortunately, no analysis of the Bartestree rock

---

[1] See A. Harker, 'The Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. 1904, p. 351, and Journ. Geol. Chicago, vol. viii (1900) p. 394.

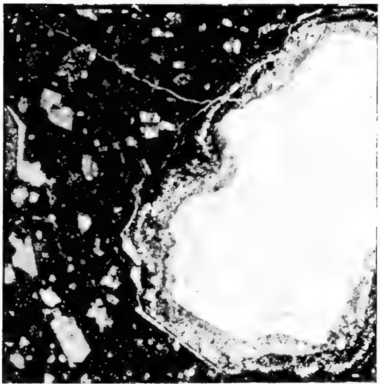
[2] 'The Tertiary Igneous Rocks of Skye' *op. cit.* p. 362.

[3] The memoir has been published since the above was written.

[4] 'The Igneous Rocks of Arkansas' Ann. Rep. Geol. Surv. Arkansas for 1890, vol. ii (1891) p. 393.

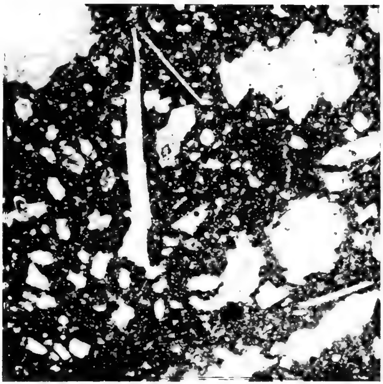
[5] S. H. Reynolds, 'The Basic Intrusion of Bartestree' Q. J. G. S. vol. lxiv (1908) p. 501.

Fig. 1.



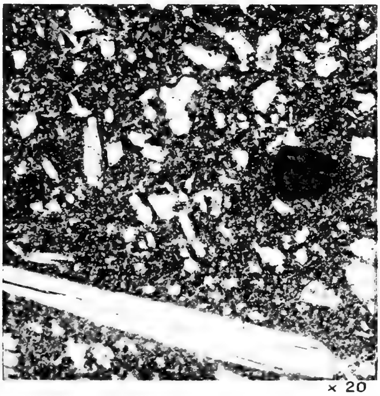
× 20.

Fig. 2.



× 20.

Fig. 3.

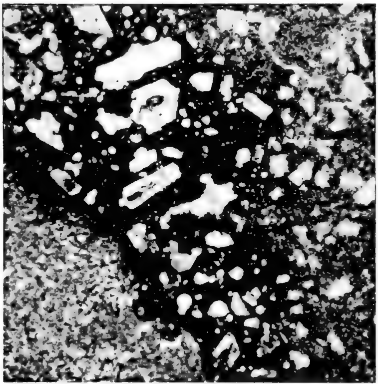


× 20

Fig. 4.

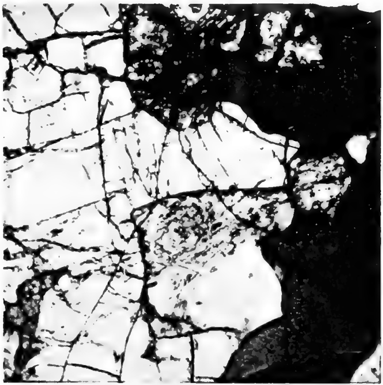
× 20

Fig. 5.



× 20

Fig. 6.



× 20

W. S. Boulton, Microp'

Bemrose Ltd., Collo., Derby.

ROCKS FROM THE MONMOUTHSHIRE MONCHIQUITE-DYKE.

has been published, but it is significant that one of the variants of that composite dyke is a dark, heavy, and very basic analcite-dolerite or teschenite, with a silica-percentage of 43·03 and specific gravity = 2·88 (*op. cit.* p. 509).

With regard to the age of the Monmouthshire intrusion, the only certain fact is that it is later than the Upper Old Red Sandstone. In the memoir referred to above, Dr. Flett discusses the age of the monchiquite and olivine-dolerite dykes of Colonsay that have a north-westerly trend, and says that

> 'they belong to a series which has a wide distribution in Argyllshire and the adjacent part of the West Highlands.'[1]

That they are post-Carboniferous seems certain, but whether they are of the same age as the Tertiary dolerite-dykes of Skye and other parts of Western Scotland is still an open question, and need not be discussed here.

The Beinn Dearg dykes of the Red Hills of Skye, which are low in silica, comparatively poor in alumina, and rich in magnesia, are regarded by Mr. Harker as a

> 'highly specialized derivative from the hypothetical common stock.'[2]

It may be that the monchiquites of Colonsay are a still more pronounced variant in this same basic series of Western Scotland.

In much the same way, the Monmouthshire monchiquite and the dolerite of Bartestree may be related to each other, and derived ultimately from a common magma; so that, whereas the teschenite of the Bartestree dyke shows some considerable departure from the normal stock, the monchiquite may be regarded as a more extreme variant.

VII. SUMMARY.

The rock here described is the only example of a monchiquite so far recorded in England and Wales. It is intrusive in the Upper Old Red Sandstone of Monmouthshire, either as a wide irregular dyke or a plug.

It is remarkable for its large corroded phenocrysts of augite, biotite, and olivine.

It has incorporated many lumps and chips of the country-rock, with the usual metamorphic changes in the xenoliths; and in their vicinity the rock becomes locally, but to a very subordinate extent, a limburgite, with the more normal glassy base.

Cognate xenoliths of picrite are also included, which probably represent the more abyssal equivalent of the monchiquite.

Petrographically and chemically it is very like the monchiquites and camptonites of Scotland, especially of Colonsay; and it may be regarded as a specialized and ultrabasic variety of the same magma that yielded the analcite-dolerite of Bartestree, near Hereford.

---

[1] 'The Geology of Colonsay & Oronsay, with part of the Ross of Mull' Mem. Geol. Surv. 1911, p. 41.

[2] 'The Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. 1904, p. 326 (see analysis on p. 325).

I wish to express my indebtedness to Dr. Flett for very kindly advice, for examining some of my rock-sections, and for the loan of specimens from Colonsay; to Mr. Herbert H. Thomas for calling my attention to the Colonsay rocks; and to Prof. Sollas for the use of the apparatus in the University Geological Laboratory at Oxford for photographing the rock-sections.

EXPLANATION OF PLATE XXXVII.

Fig. 1. Slide M 411. Showing a nearly colourless augite (chrome-diopside)-phenocryst with corrosion-border and added zone of purple-brown augite. The rest of the field is the dark-brown monchiquite matrix, with small crystals of augite and olivine. × 20 diameters.

2. Slide M 404. Monchiquite with plates of biotite, the two near the top of figure enclosing an olivine-crystal. In the left upper corner and on the right are larger corroded and decomposed olivine-crystals. The ground-mass is dark grey, with octahedra of iron-ore and small olivine-crystals. × 20 diameters.

3. Slide M 403. Monchiquite, showing in the lower part of the figure a reddish-yellow biotite-crystal, and to the right of the centre a dark reddish-brown chromite-granule. The dark-grey ground-mass encloses small prisms of pale-brown augite, with a few small olivine-crystals and granules of iron-ore. × 20 diameters.

4. Slide M 401. In the lower right-hand corner is part of an Old-Red-Sandstone xenolith (measuring half an inch across). Three lapilli of dark-brown and reddish-brown palagonite, enclosing crystals of augite and small round vesicles, make up half the field. They are embedded in a colourless or light-grey matrix, consisting mainly of carbonate, with small lapilli of glass and granules of quartz. × 20 diameters.

5. Slide M 420. Junction of the Old Red Sandstone xenolith, showing the local development of basic glass. On the left is part of the xenolith, with corroded border; in the centre is dark-brown glass enclosing pale-brown augite-crystals and vesicles; on the right is the monchiquite with analcite ground-mass. × 20 diameters.

6. Slide M 415. Cognate xenolith of picrite. To the left and in the centre is a large plate of very pale yellowish-green chrome-diopside, enclosing serpentinized olivine. Near the top is another area of decomposed olivine, partly surrounded by augite; while the dark patch on the right is deep greenish-yellow translucent chromite. × 20 diameters.

Discussion.

Dr. J. W. **Evans** remarked on the similarity of the large augite mentioned in the paper with that described by Heddle from the volcanic neck at John o' Groats. He also referred to the fact that the analcime ground-mass of monchiquites represented the only case known in the consolidation of rock-magmas, in which a eutectic residue was a definite chemical compound instead of a mixture. The low melting-point of analcime, which was less than that of any other original mineral constituent of igneous rocks, was due to the fact that it contained water; and it was the presence of water in the magma that determined the occurrence of monchiquite, rather than that of a basic rock containing plagioclase and nepheline.

17. *The* CARBONIFEROUS SUCCESSION *in* GOWER (GLAMORGANSHIRE), *with* NOTES *on its* FAUNA *and* CONDITIONS *of* DEPOSITION.

By ERNEST EDWARD LESLIE DIXON, B.Sc., A.R.C.Sc., F.G.S., and ARTHUR VAUGHAN, M.A., D.Sc., F.G.S.

(Read March 9th, 1910.)

[PLATES XXXVIII–XLI.]

CONTENTS.

I. INTRODUCTION [E. E. L. D. & A. V.].

THE object with which the Avonian rocks of Gower (figs. 1 & 2) described in the present paper were examined was primarily the comparison of their faunal sequence with that of Bristol and other parts of the South-Western Province. In this connexion valuable pioneer work on parts of the sequence had already been done by

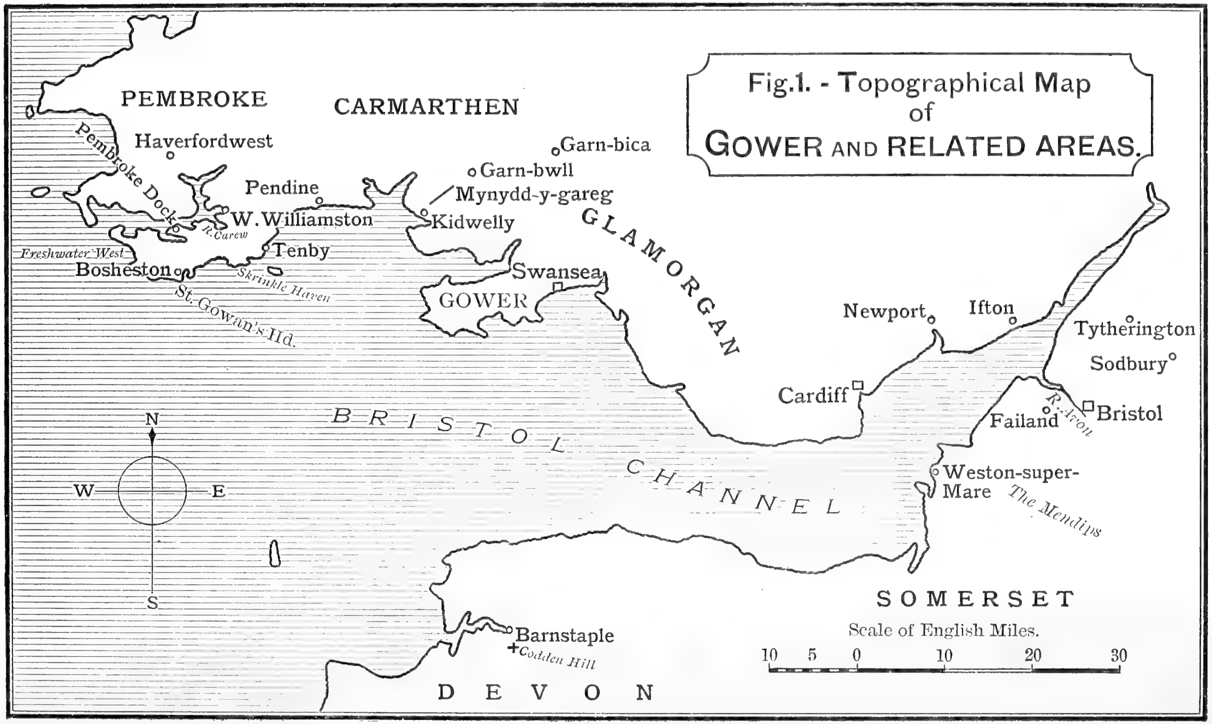
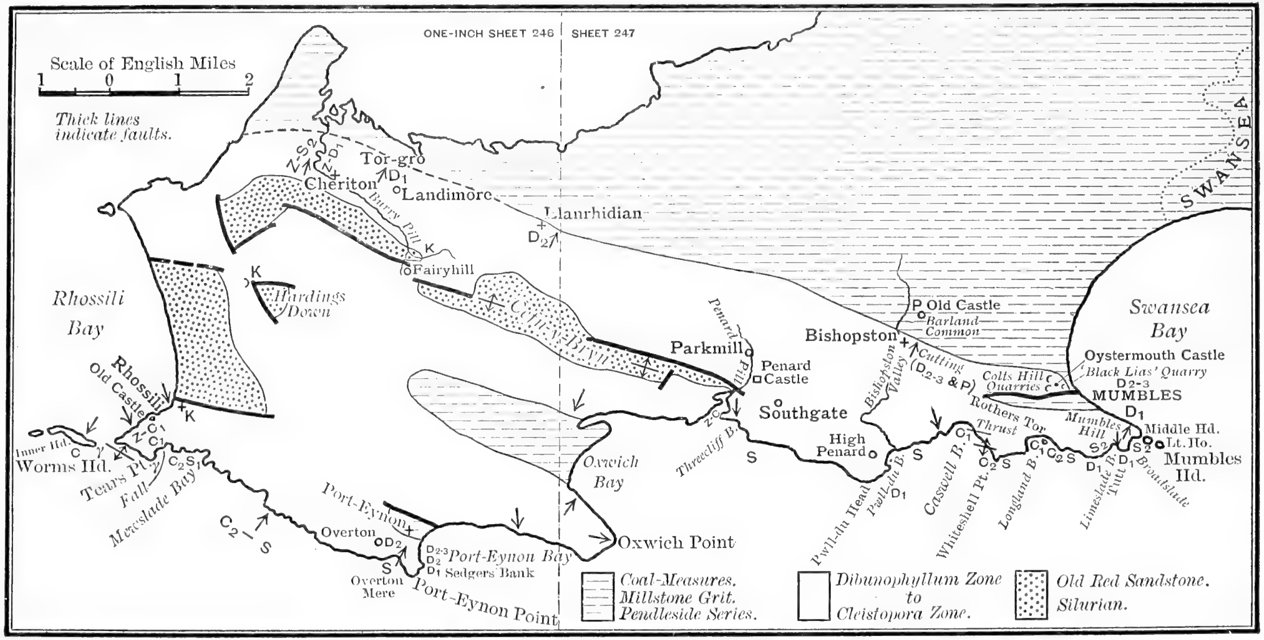


Fig. 1. - Topographical Map of GOWER AND RELATED AREAS.

Fig. 2.—*Geological map of Gower, based on those published by the Geological Survey.*



[Deposits of later age than the Carboniferous have been omitted.]

Dr. W. B. Gubbin[1]; and it was desired that our knowledge should be extended to the whole development, as also to the relationship of the zones that are based on brachiopods and corals[2] with the representative of the Pendleside Series which had been recognized in Gower by Dr. Wheelton Hind.[3] For in Gower alone of the whole province was such a representative known.[4] Between 1899 and 1902 the area had been mapped by the officers of H.M. Geological Survey, Dr. A. Strahan, Mr. R. H. Tiddeman, and Mr. B. S. N. Wilkinson, and our work was greatly facilitated by the knowledge then obtained, which was generously placed at our disposal and has since (in 1907) been published in the official maps and memoirs.[5]

Our joint field-work, the examination of the Mumbles-Bishopston ground and the southern coast, was carried out in 1905, and in the following year one of us (E. E. L. D.) extended the work into the north-western part of the area in connexion with the Geological Survey; a summary of the information then obtained has since been published.[6]

II. Lithological Characters of the Zones [E. E. L. D.].

The Avonian rocks of Gower (see map, fig. 2, p. 479, based on the Geological Survey maps previously mentioned) form part of the southern margin, the 'South Crop,' of the South Wales coal-basin. They present several outcrops, ranging west-north-west on the whole, as they have shared in the powerful Armorican folding about axes having that direction, which is the dominant structural feature of the whole area. The folds are chiefly elongated periclines, and the several Avonian outcrops along the limbs are continuous one with the other.

These outcrops represent the deposits of an area of the Avonian sea which extended for some distance both eastwards and westwards (that is, parallel to the coast-line lying at no great distance to the north), and northwards and southwards; and the bearing of this fact on the development in different districts will be pointed out.

In the east, between Mumbles and Cefn-y-Bryn, only one major fold—the Cefn-y-Bryn pericline—appears above the sea, and the Lower Carboniferous rocks which form its eastward-pitching 'nose,' though presenting several outcrops on account of minor folding, may be grouped together as the Eastern District. But in the west, rocks of the same age occur over a wider extent of country. At

---

[1] Proc. Bristol Nat. Soc. ser. 4, vol. i (1905) p. 42.

[2] A. Vaughan, Q. J. G. S. vol. lxi (1905) p. 181.

[3] Geol. Mag. 1902, p. 485; *ibid.* 1904, pp. 402, 585–87.

[4] Recently, Dr. Hind has correlated some beds at Tenby with the Pendleside Series, Proc. Geol. Assoc. vol. xxi (1909) p. 179.

[5] The Swansea sheet (N. S. 1-inch map 247) and 'The Country around Swansea' 1907; the Worms-Head sheet (N. S. 1-inch map 246) and 'West Gower & the Country around Pembrey' 1907. These memoirs will be referred to as the 'Swansea Memoir' and the 'West Gower Memoir' respectively.

[6] West Gower Memoir, pp. 14–17.

present, those in the most widely separated outcrops are 4 or 5 miles apart across the strike, but they must have been deposited at a much greater distance from one another, seeing that the intervening ground is traversed by several deep folds. The northernmost outcrop, west of Llanrhidian, which is continuous along the strike with that at Mumbles, will therefore be distinguished, under the name of the North-Western District, from the southernmost, which lies between Port-Eynon Bay and Worms Head, and constitutes the South-Western District. No attempt, however, will be made to describe the whole outcrop of any part of the series.

Note.—(i) In the following descriptions the dolomites, unless otherwise described, are 'contemporaneous,' that is, they have been deposited as calcite or aragonite, but altered to dolomite by the waters of the Carboniferous sea,—shortly, therefore, after deposition. They are concluded to have had this origin on account of a variety of evidence, part of which has been published in the Swansea Memoir, pp. 13–20, pls. i & ii. 'Vein-dolomites,' due to a later mineralization, and described in the same memoir, are frequent, but have in some cases no obvious relationship with any visible vein, appearing, then, to have resulted from diffuse percolation. Such cases may occur in rocks which have been partly altered 'contemporaneously.' (ii) Thicknesses, unless stated to have been measured directly, have been estimated from outcrop, dip, and height; the locality is added in each case.

(1) Eastern District.

Lower Avonian.

K = *CLEISTOPORA* Zone.

Lithological characters.—So far as known, Lower Limestone Shales, that is, grey shales with subordinate fossiliferous limestones,[1] the latter weathering soft and ochreous. For Lower Limestone Shales underlie, probably at no great distance, the beds in Threecliff Bay referred to horizon β, and the position of horizon β is immediately above the *Cleistopora* Zone.

Limits.—Relations to beds above and below not seen.

Exposures.—Poor; near Penard Castle, and at Southgate.

---

[1] The 'limestone flags,' 200 feet thick, exposed along Penard Pill below Parkmill, and referred to this zone by Dr. Gubbin, Proc. Bristol Nat. Soc. ser. 4, vol. i (1905) pp. 52–53, belong (on the evidence of the fauna which we have obtained from them) to Z_1, together, probably, with horizon β. Their proximity to the Old Red Sandstone, mentioned by Dr. Gubbin, is due to a fault.

Z = *ZAPHRENTIS* Zone.

Z_2 = subzone of *Zaphrentis konincki* Edw. & H., Carr.
Z_1 = subzone of *Spirifer clathratus* M'Coy.
Horizon β.

Lithological characters.—The lowest part of the Main Limestone[1]; in descending order:—

Z.—Dolomites similar to the *Laminosa* Dolomites, that is, dark grey, finely crystalline, with small scattered nests of calcite and dolomite; interbedded with unaltered, thinly-bedded, crinoidal limestones, which are abundant in the lower part but die away to a great extent, upwards, at about 100 feet above the base of the Zone. Through the lowest 50 feet or so occur impersistently-tabular cherts and beekitized fossils.

Horizon β.—More thickly-bedded, crinoidal limestones; several yards exposed, but base not seen.

Fauna.—See pp. 544–45.

Thickness.—Of horizon $\beta + Z_1$:—about 150 feet (Threecliff Bay), on the assumption that the unexposed basal part of horizon β is not much more than 10 feet thick. Of Z_2 alone not determinable without difficulty; of the dolomite-group, Z_2 + *Laminosa* Dolomites, 320 feet (Threecliff Bay).

Limits.—Horizon β, at the junction of the *Cleistopora* and *Zaphrentis* Zones, is probably also the junction of the Lower Limestone Shales and the Main Limestone. The junction of Z_1 and Z_2 is not marked by any appreciable lithological change; the top of Z_2 could not be localized, owing to the prevalent dolomitization, but evidently is also not defined lithologically.

Typical exposure.—Threecliff Bay, east side:—horizon β and the rest of the zone in sequence.

C_1 = Lower Subzone of the *SYRINGOTHYRIS* Zone.

2. *Caninia* Oolite.
1. *Laminosa* Dolomites.

The presence or absence of horizon γ in Eastern Gower could not be determined, owing to the dolomitization prevalent through Upper Z and Lower C_1.

Lithological characters and thickness.—In descending order:—

2. *Caninia* Oolite. As a rule a remarkably pure limestone, distinguished from neighbouring horizons by its light-grey, often white colour and thick bedding, but especially by the purity

---

[1] This is merely a convenient name for the main limestone-mass of the Lower Carboniferous; no relationship to the Main Limestone of the North of England is implied.

of its oolitic structure[1]—other material, such as crinoid-ossicles and smaller organisms, being largely confined to subordinate bands, while larger fossils amount to little more than a few beds of brachiopods or *Bellerophon* and an occasional *Syringopora*. Some bands, generally current-bedded, show evidence of contemporaneous erosion in included, sometimes rounded, fragments of oolite. Minute to microscopic ooliths are frequent, in places to the exclusion of others, especially towards the top. There, also, more often than elsewhere, the rock is dark in colour. Chert is unknown, unless represented by big, light-grey, concentrically-zoned siliceous nodules (Threecliff Bay); these, however, have not been critically compared with the siliceous aggregates found later in North-Western Gower. The rock passes up from the dolomite below, through intermediate phases in which the ooliths are less dolomitized than the matrix; and in places dolomite recurs in bands in the lower part.

Thickness.—160 feet (Threecliff Bay); 125 and 70 feet (Caswell Bay anticline); 150 feet (Longland Bay).

1. *Laminosa* Dolomites. Dark-grey or black, finely-crystalline dolomites,[2] chiefly representing fairly thin-bedded, crinoidal limestones, with here and there a few such beds still unaltered; towards the top, where the dolomite is rather paler and more thickly-bedded than below, it may be seen in places that it represents oolite. As a rule, dolomitization has obscured or obliterated most of the original constituents, including, among the fossils, some of the crinoid-ossicles, highly-resistant though they be. A feature of the crinoidal dolomites and others of the same type (as, for instance, those in Z) is the sporadic occurrence, throughout their mass, of small nests, up to several inches in diameter, of a coarsely-crystalline mosaic of glassy calcite and milky-white dolomite; on wave-worn surfaces these nests contrast strongly with the surrounding black rock. Many of them appear, from traces of organic structure still preserved, to have originated, partly through the alteration and recrystallization of calcareous mud, inside fossils with internal cavities, such as gasteropods and certain corals.

   Thickness indeterminable (see Z_2).

Fauna.—Little known (p. 546), the *Laminosa* Dolomites having lost most of their fossils, and the *Caninia* Oolite never having had many.

---

[1] Under the microscope the grains, like those of most of the oolites of the Gower Avonian, show a radial-fibrous as well as a concentric structure, and differ thus from the S_2-pisolites. They are approximately spherical, with a diameter which in many is about 0·4 mm. and is seldom greater than 0·6 mm., but in the smallest measures 0·13 mm. or less.

[2] The completeness of the dolomitization may be gauged from the fact that an average sample, analysed for commercial purposes, was found to contain 20·35 per cent. MgO, the percentage in $CaCO_3 . MgCO_3$ being 21·9.

Limits.—The boundary between the two groups is merely the somewhat uneven level at which the dolomitization characteristic of the lower shows greatest diminution when followed upwards. Unevenness of the level on a large scale would explain the inconstancy in thickness of the *Caninia* Oolite, should it be found that the total thickness of C_1 is fairly constant.

The top of the *Caninia* Oolite is sharply defined, and appears, from the character of fragments in the overlying bed, to have been slightly eroded, in places at least, prior to the deposition of C_2, though it is not channelled or corroded as at West Williamston (Pembrokeshire).[1]

Typical exposures.—Threecliff Bay, east side. Caswell Bay, east side :—several outcrops due to folding and faulting. This disturbance, which amounts to an anticline the crest of which has sagged down into a deep syncline with an overthrust from the north for its northern limb, has been described and figured by Dr. A. Strahan.[2] The 'thick bed of light-coloured oolite' referred to by him is the *Caninia* Oolite, and the 'dark and thin-bedded limestones' beneath are the *Laminosa* Dolomites together, possibly, with the top of Z_2. Thus the *Caninia* Oolite has three complete outcrops and, in addition, a partial outcrop due to a strike-fault in the southern limb of the anticline. Longland Bay, north side :—the *Laminosa* Dolomites with, probably, the top of Z_2; in and near Rothers Tor, the *Caninia* Oolite.

Upper Avonian.

C_2=Upper Subzone of the SYRINGOTHYRIS Zone.[3]

2. Standard limestones.
1. *Modiola* phase.[4]

Lithological characters.—Of the beds in descending order :—

2. Standard limestones, that is, limestones with a standard marine fauna, largely crinoids, corals, and brachiopods. The limestones are chiefly light-grey, rather thickly-bedded, and highly fossiliferous, but are in some cases dark and more thinly-bedded, especially those containing many gasteropods. Beds of dark, finely-crystalline dolomite and partings of shaly limestone occur, but are quite subordinate. In the gasteropod-beds the gasteropods are replaced in many cases by dolomite, even where the surrounding matrix has remained quite unaltered. Selective dolomitization of this kind is found only in organisms which have been originally aragonitic, such

---

[1] 'The Country around Haverfordwest,' Mem. Geol. Surv. (in the press).

[2] Swansea Memoir, p. 8, fig. 1.

[3] As explained in § VI, the dividing-line between Lower and Upper Avonian is now taken at the base of C_2.

[4] The meaning of this term is explained on pp. 512 *et seqq.*

as gasteropods and orthocerates, but occurs at many Avonian horizons throughout the South-Western Province. In view of the instability of aragonite, this phenomenon is readily explicable, but implies that the organisms were still aragonitic when dolomitized. Further, the wide occurrence of the phenomenon, taken in conjunction with the short life of organic aragonite under the conditions accompanying vein-dolomitization, supports the conclusion, based on other considerations, that the dolomitization was 'contemporaneous.' Where there is no independent evidence of 'contemporaneous' dolomitization, it is found that organic aragonite has been replaced by coarse calcite-mosaic.

In places, the lowest bed contains fragments of the highest of the deposits of the underlying *Modiola* phase.

1. *Modiola* phase. A variable group of limestones, dolomites, breccias, and more or less calcareous shales or clay-mudstones, thinly bedded to finely laminated or papery; grey, dull buff, or greenish in colour (where free from Triassic reddening). The limestones, some of the argillaceous varieties of which are nodular and concretionary,[1] are either fine-grained to compact, or very finely oolitic (these resembling parts of the *Caninia* Oolite) or, occasionally, 'pisolitic.' Crinoidal limestones are rare, and are merely thin laminæ. Many of the fine or compact limestones and dolomites fracture conchoidally, and resemble 'chinastone-limestones'; but some are finely-laminated: they are calcite- or dolomite-mudstones (see p. 516). Either kind, but, it appears, more frequently the dolomitic, has recrystallized in places to calcite- or dolomite-mosaic of fine to coarse grain. Some finely-crystalline dolomites, however, may be 'contemporaneons' replacements of originally-calcitic rocks.

   Ordinary detrital matter is frequent. The mudstones contain fine clayey material, which may exceed the calcareous, or, in some cases, fine quartz-sand. Breccias, of limestone and clay-mudstone fragments, measuring up to several inches in length, set in an argillaceous, calcareous, or fine-sandy matrix, may occur at any horizon. The fragments are similar in structure and fossils, either to some of the intercalated beds, or, in the case of some in the basement-bed, to the *Caninia* Oolite below, and evidently have been derived from both sources by contemporaneous erosion. Undoubtedly far-travelled material, other than clay and sand, appears to be absent, and the fragments show little, if any, rounding.

   Some beds, however, have a brecciated structure, due in part to the penetration of an alien matrix into calcite-mudstone, apparently along irregular cracks. The origin of the structure

---

[1] The concretionary structure here mentioned is the type usual in argillaceous formations, not the peculiar structure of the 'concretionary beds' of the Avon.

is uncertain, but the mud appears to have been brecciated *in situ* by desiccation and cracking, without complete separation into fragments (see p. 514, footnote 6).

It may be noted that where a calcite-mudstone has succeeded a breccia with uneven upper surface, it has filled up the inequalities and formed a level surface; in the same way, but on a larger scale, a compact limestone, the lowest bed of a thin *Modiola* phase, fills up the inequalities in the upper surface of the conglomerate at Pendine (Carmarthenshire), described by Dr. Strahan.[1]

True chert is unknown, but quartz in the peculiar form of minute, colourless and milky-white, zoned nodules of the size of sand-grains, has been noticed in a microscope-slide of one of the laminated limestones.

The following section illustrates the character of the phase and its relations to the beds above and below:—

Junction of C_1 and C_2.—Southern outcrop on the east side of Caswell Bay.

	Thickness in feet.
9. Crinoidal limestones, resting sharply on	
8. Calcite-mudstone, white-skinned, filling inequalities in	
7. Breccia: consisting partly of black calcite-mudstone, some of which is fragmentary, and some, though penetrated by the matrix, apparently not completely broken up. The matrix is mudstone and very fine sandstone. With Bed 8.	5
6. Thinly-bedded, fine-grained limestones, including oolites. With Beds 4 & 5	11
5. 'Pisolite,' consisting of black, flattened, concentrically-laminated, calcitic 'pisoliths,' up to 0·75 inch in diameter, set in grey finely-crystalline dolomite; a few inches thick.	
4. Thinly-bedded to laminated, compact, argillaceous limestones.	
3. Dark limestone and black shale, passing into	1¼
2. Clay-mudstone, with angular or subangular fragments, up to several inches in diameter, of fine-grained, dark oolite such as is found at the top of the *Caninia* Oolite; lenticular beds of black limestone in the upper part. Rests sharply on	1½
1. Fine-grained oolite, light or dark grey.	
Total thickness of *Modiola* phase	18¾

Bed 1 is the top of the *Caninia* Oolite (C_1); Beds 2–8 constitute the C_2 *Modiola* phase; and Bed 9 is the base of the standard limestones of C_2.

The base of C_2 presents the features described above, which, in conjunction with the faunal peculiarities, show that it constitutes a *Modiola* phase, wherever it has been examined in the eastern district, except in Longland Bay. There it consists of a group, a few yards thick, of dark, finely-crystalline dolomites, similar to the *Laminosa* Dolomites but containing

---

[1] 'The Country around Carmarthen' Mem. Geol. Surv. 1909, p. 81.

abundant specimens of *Bellerophon*; this, though sharply separable, on account of its far more intense dolomitization, from the immediately succeeding beds (limestones with dolomitized *Bellerophon*), forms part of the standard limestones.

Fauna:—

2. Standard limestones.—Rich, especially in corals and brachiopods; crinoid-remains ubiquitous. In their fossils the lowest beds differ somewhat from the rest (pp. 542–43, 546–47).
1. *Modiola* phase.—Poor, consisting in most beds merely of fish-fragments, abundant ostracods, a *Spirorbis*-like annelid, or abundant *Calcisphæra (?)*.[1] The calcareous alga (*Girvanella*) may be present, poorly preserved, in some coats of the 'pisoliths.' Standard forms—crinoid-ossicles and foraminifera—are known only from rare laminæ, in which, however, they are abundant.

Thickness.—Total, between 200 and 250 feet (Threecliff Bay); 350 feet (Longland Bay). The discrepancy does not appear to be due to faulting. Of the *Modiola* phase alone, 16 to 20 feet (direct measurement).

Limits.—The change at the top of the *Modiola* phase to standard limestones is abrupt, and is accompanied in places by contemporaneous erosion, which has been sufficient locally, as may be seen in Caswell Bay, to cut out some of the highest beds of the phase. The top of the subzone, that is, C–S, the junction of C_2 and S_1, is not marked by any appreciable lithological change. For this reason, it is frequently useful to group the subzones C_2 and S_1 as one division, $C_2 + S_1$.

Typical exposures:—

2. Standard limestones.—Threecliff Bay, east side. Caswell Bay,—several exposures, the southernmost on the east side being the best. Longland Bay, east side.
1. *Modiola* phase.—Threecliff Bay, east side, and Caswell Bay, —several complete exposures at each place, the display in the syncline being particularly good. Note:—The outcrops of the *Modiola* phase are easily found by reference to the underlying *Caninia* Oolite.

S = *SEMINULA* Zone.

S_2 = subzone of *Productus* '*cora*' D'Orb., mut. S_2.
S_1 = subzone of *Caninia bristolensis* Vaughan.

The subzones were not delimited, nor examined so closely as in the South-Western District; but the sequence was seen to be much the same as in that district.

---

[1] The organisms provisionally referred, here and on subsequent pages, to *Calcisphæra* are isolated spheres of calcite, with an average diameter of 0·05 to 0·1 mm., the walls of which are thin and have a radial-fibrous structure.

Lithological characters.—In descending order:—

S_2:—2. *Modiola* phase. Chiefly 'pisolites,'[1] oolites, foraminiferal limestones, and calcite-mudstones, the latter including the unfossiliferous white-weathering variety called, from their porcellanous appearance, 'chinastone-limestones'; fossils abundant (individuals, not species), notably *Seminula* in beds with a dark, fine-grained matrix; some beds dolomitized. Contemporaneous erosion is evidenced in some of the oolites by irregular fragments, also of oolite, measuring up to 2 feet in length; in such beds dolomite, if present, is more abundant in the matrix than in the fragments.

1. Standard limestones. Oolites, with some pisolites and fine-grained limestones; in many, few macroscopic fossils, but others are coral-,[2] brachiopod-limestones, etc. Contemporaneous erosion is evidenced in the same way as in the overlying group. Dolomites recur at intervals.

S_1:—Limestones, largely made up of crinoids, corals, brachiopods, and, in some dark impure beds, gasteropods; dolomitic beds at intervals; chert-nodules and beekitized fossils, extending, with the gasteropod-beds, possibly into the base of S_2 as in the South-Western District.

Fauna.—See pp. 547-48. The *Modiola* phase has not yielded any of the peculiar forms generally present in such phases.

Thickness.—Of the whole zone, about 1250 feet (Longland Bay). The subdivisions were not separately measured, but S_2 was by far thicker than S_1.

Limits.—The upper limit of S_1 was not examined. The two parts of S_2, though separable in a broad way, pass insensibly one into the other, the incoming of the pisolites abundant in the upper part being quite gradual. The upper limit of S_2 is marked by a rapid and considerable lithological and faunal change, thus:—

Junction of S_2 and D_1.—Generalized from several exposures.

D_1: Pseudobreccias of limestone or dolomite, with a typical D_1-fauna from the base upwards; in places a thin basal oolite.

Passage-beds: Current-bedded, fine-grained, and in part oolitic limestones with *Cyathophyllum*; 15 to 20 feet.

S_2: *Modiola* phase. Limestones of the types previously mentioned; *Seminula ficoides* in crowds, at intervals up to the top.

---

[1] Much of the 'pisolite' might more properly be termed 'contemporaneous breccia,' for it consists largely of more or less irregular masses, of various sizes, of dense, amorphous-looking limestone, some only of which show a pisolitic structure. These latter consist of a layer of dense calcite, of fairly uniform thickness, around an organic nucleus, generally a *Seminula* (double-valved) or a coral-fragment, but they rarely, if ever, have a concentric structure of several well-defined layers, though such a structure is frequent in the S_2-pisolites of the Avon. Under the microscope it is seen that the dense material may contain *Girvanella*-like tubules, but also that much of it is structureless and of exceedingly fine grain, being devoid, apparently, of any necessary connexion with these tubules.

[2] None of the coral-limestones are unbedded through great thicknesses, and thus differ from coral-reef limestones.

Typical exposures.—Threecliff Bay, east side. Pwll-du Bay. Whiteshell Point:—lower part of the zone. Longland Bay, east side:—the whole zone, in sequence with those above and below. Limeslade and Broadslade (Bracelet) Bays:—much of S_2, the junction with D_1 at Tutt and at Mumbles Head (in both the Middle Head islet and the adjacent cliff). Bishopston Valley:—several exposures, including one of the same junction at the Sker.

D=*DIBUNOPHYLLUM* Zone.

The development of the upper part of this zone in Gower differs in important respects from that in the Bristol and Dublin districts, and has therefore been subdivided on somewhat different lines. In Eastern Gower the following groups are present. Above the lower part of the zone, which is a normal development of D_1, comes a group of limestones, connected faunally with both D_1 and D_2, and, therefore, referred to as D_{1-2}. This forms the top of the Main Limestone, and is followed by a calcareo-argillaceous group, the 'Upper Limestone Shales' of the Geological Survey,[1] which probably represents part of D_2, but certainly extends to a higher horizon and is therefore known as D_{2-3}. A resemblance of some of its fossils to forms which are common in the *Zaphrentis* Zone led at one time, before the D_3-fauna of County Dublin was known, to some controversy as to the systematic position of D_{2-3}. It is now clear, however, that, as Dr. Wheelton Hind maintained,[2] it occurs at the top of the Viséan.

It is succeeded by an almost purely argillaceous group, which is included in the Millstone Grit by the Geological Survey and has been recognized by Dr. Hind as a representative of the Pendleside Series. And, though it is possible that the Pendleside Series is a phasal equivalent of part of the sequence of coral-and-brachiopod zones of some regions, the name *Posidonomya* Zone (P), already in use for it, will be retained.

$D_1=\theta\phi$ Subzone.

Lithological characters.—Chiefly light-grey, thickly-bedded limestones, many partly dolomitized. The limestones are predominantly of the type, peculiar in Gower to the D-zone, characterized by the remarkable 'pseudobrecciated' structure which has been described by Mr. Tiddeman[3] and forms the subject of a separate note (p. 507). Besides much obviously subsequent

---

[1] The disadvantages attaching to other names, such as 'Bishopston Beds,' which have been applied to this group, have been stated by Dr. Strahan in the Swansea Memoir, p. 21. It may be added that, as delimited by Mr. E. B. Wethered & Prof. C. Lloyd-Morgan, the 'Upper Limestone Shales' of the Avon,—for which Buckland & Conybeare originally proposed the name,—include lower horizons than those of Gower.

[2] Geol. Mag. dec. 5, vol. i (1904) pp. 585–87.

Swansea Memoir, p. 10. He observes the persistence and high horizon of these rocks, and groups them together as the 'Mumbles Head Beds.'

dolomite, there are occasional large irregular bodies of dolomite, similar in its coarse grain and its association with clay to the dolomite characteristic of pseudobreccias, but evidently of somewhat different origin. Another peculiar feature of the pseudobreccias, noted by Mr. Tiddeman and difficult of explanation, is the occurrence of numerous pits, as a rule circular, 18 to 30 inches in diameter and a foot deep, but also irregular and larger, distributed evenly over the upper surface of some of the beds (see Pl. XXXVIII, fig. 1, taken from an example in the North-Western District); these pits are filled with grey, buff-weathering clay or, less frequently, with coarse, light dolomite, and, at some levels at least, underlie thin beds of clay continuous with their infillings. A few cases have been observed of a pseudobreccia passing laterally, in a short distance, into clay with limestone-rubble.

Subordinate to the pseudobreccias are limestones of ordinary types. In places a coarse-grained oolite marks the base of the zone, and other limestones, dark or light, are intercalated at higher horizons. The zone is, however, further distinguished by the presence of thin coaly layers, also noticed in the first place by Mr. Tiddeman (*loc. cit.*). Some, though thin and valueless like the others, resemble many true coal-seams in their character and association with underclay, and have probably originated in the same way. Thus, an unusually good exposure at Colts Hill, of one lying at a considerable distance from both the top and the bottom of D$_1$, showed in descending order:—

[Section near thin coal in D$_1$.—Southern quarry at Colts Hill.]

	Thickness in feet.
4. Limestone pseudobreccia, with a standard marine fauna.	
3. Coal-smut and finely-laminated, carbonaceous shale; in all about	1½
2. Underclay with frequent rootlets and much pyrite; passing upwards into shale (3)	3½
1. Limestones, pseudobrecciated or ordinary. The upper surface of the highest is soft, but uneven (with projecting corals), and it is uncertain whether it shows a passage or a non-sequence into (2).	

There is no need to postulate a different origin for the smut-bed at Oxwich Point, though found by Mr. Tiddeman to contain many small gasteropods.

Fauna.—See pp. 548–49.

Thickness.—Between 400 and 450 feet (Pwll-du Bay).

Limits.—The faunal change to D$_{1-2}$ is not accompanied by any noticeable lithological change.

Typical exposures.—Pwll-du Bay and Head. Mumbles Head (including the Middle Head and the lighthouse islets):—much of the subzone, the dolomitic pseudobreccias conspicuous. North-north-eastern face of Mumbles Hill:—dolomitic pseudobreccias, in several cases 'pitted.' Oystermouth (Colts Hill southern quarry):—

pseudobreccias, unweathered, contrasting strongly in appearance with the weathered rocks on the coast. Bishopston Valley:—the outcrops of the D Zone in the sides of the valley are too narrow to accommodate its probable thickness, the cause of the discrepancy being, doubtless, unexposed strike-faulting.

D_{1-2}.

Lithological characters.—Much as in D_1, but the pseudobreccias disappear in the upper part. The following section shows the sequence at Colts Hill, and also the relations to the beds (D_{2-3}) above:—

D_{1-2} and D_{2-3}.—Colts Hill.

	Thickness in feet.
D_{2-3}:—'Black lias,'—thinly-bedded, black, argillaceous limestones and shales, one of the latter a foot thick; cherts.	
D_{1-2}:—3. Thickly-bedded, fine-grained limestones including oolite; the highest few feet dark, with black cherts, the rest light grey and chertless; pure, except for some dolomite and occasional shaly partings; about	50
2. Dark, shaly nodular limestone, slightly dolomitized, the nodules elongated	1–2
1. Thickly-bedded, light-grey limestones, including pseudobreccias, continuous with those of D_1; base not determined owing to poorness of exposure, but thickness probably about	60

Fauna.—See pp. 549 & 551. The *Productus* Band at Colts Hill occurs at the top of Group 1. *Caninia cornucopiæ*, mut. D_{2-3} was observed in the dark limestone immediately below D_{2-3}.

Thickness.—Uncertain, but not more than 120 feet (Colts Hill).

Limit.—The change to D_{2-3}, which is considerable as regards both fauna and rock-types, is almost abrupt, and is emphasized by weathering, as may be seen at Colts Hill: D_{1-2} remaining hard limestone, but D_{2-3} becoming soft, clayey 'rottenstones.' The change is foreshadowed in the highest few feet only of D_{1-2}; there the fauna includes one of the corals abundant in D_{2-3}, while the rock is dark and contains dark cherts.

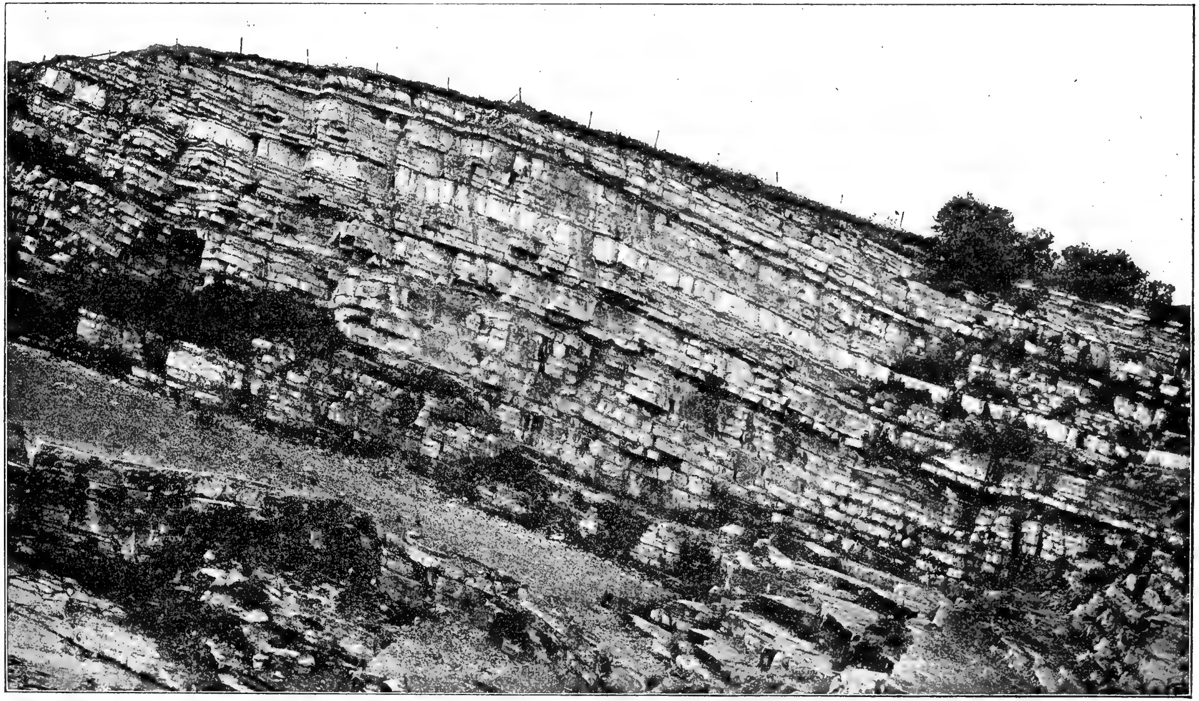
Exposures.—Pwll-du Head: top of cliff 300 to 400 yards south of High Penard. Colts Hill northern quarry and an old face between this and the southern quarry.

D_{2-3}.

[The 'Upper Limestone Shales' of the Geological Survey.]

Lithological characters.—Limestones and shales with cherts, the whole known locally as 'black lias.' The limestones are thin—generally less than 3 feet thick—and evenly bedded (fig. 3, p. 492); almost invariably dark-grey or black, with a white skin or crust of impurities where weathered; crinoid-débris

Fig. 3.—D_{2-3} *limestones and shales in the 'Black Lias' Quarry at Oystermouth.*



T. C. Hall photo. (Geol. Surv. Colln.).

and fine-grained matrix in varying proportions. They are argillaceous and some, at least, are dolomitized—the rhombohedra being, as a rule, minute. The shale-bands and partings are more or less calcareous and, though abundant, generally less than 2 feet thick. The chert, largely made up of sponge-spicules, is abundant in some beds, either as black flinty nodules, more or less sharply defined from the matrix, or diffused and difficult to detect except under the microscope; it also occurs as beekite, replacing fossils, in some beds apparently in this form alone.

'Rottenstones': relations to the 'Black Lias.'—The 'black lias' characters are retained only where the rocks are unweathered. In places the beds, both limestones and shales, have been completely altered by decalcification and oxidation to light-grey or yellow-brown, so-called 'rottenstones'[1] and clays. The 'rottenstones' are either friable and largely argillaceous, or brittle, like porous earthenware, and partly siliceous—the latter evidently representing diffusely-cherty limestones. Many are cavernous with moulds of unsilicified fossils, and some display in sharp relief many details, hidden in unweathered material, of the structure of silicified fossils. Wavellite[2] occurs in cavities and joint-planes in the higher 'rottenstones,' as in the overlying radiolarian cherts.

The 'rottenstones' and clays differ so materially at first sight from 'black lias,' that their equivalence is masked; but the view put forward by Mr. Tiddeman,[3] that they have been derived by process of ordinary weathering from such beds, is confirmed by the relations of the two types exposed in the northern quarry at Colts Hill. There, D_{1-2}, which is carried by the dip from top to bottom of the quarry, is followed by 'rottenstones' and clays with cherts near the top, but by 'black lias' with the same fauna at the bottom. Other palæontological evidence, also, points to the equivalence of the two types: the fauna of the Bishopston 'rottenstones' being approximately the same as that of the Oystermouth 'black lias' (p. 551).

An explanation of the extensive character of the weathering which the 'rottenstones' have undergone is probably to be sought in the fact that the latter, so far as known, are situated as at Bishopston, that is, at or near the top of the partly dissected plateau which constitutes the whole of this part of Gower; whereas 'black lias' is found at lower levels, as at Oystermouth. It is believed that the conditions of minimal run-off and denudation which characterize the top of the plateau have lasted long enough to allow the rocks there to be completely weathered to a considerable depth. In the valleys, where denudation is rapid, the outcrops at lower levels are unweathered.

---

[1] None of the beds have been worked for rottenstone; they are not so fine-grained as the material of that name dug for polishing-powder on the 'North Crop.'

[2] First noticed by Logan: see Mem. Geol. Surv. vol. i (1846) p. 134.

[3] Swansea Memoir, pp. 25–26.

Fauna.—Abundant (p. 550).

Thickness.—At Oystermouth at least 175 feet, and possibly as much as 350 feet, if, as is probable, the effects, in duplicating outcrop, of the strike-fault shown on the Geological Survey map between Oystermouth Castle and Colts Hill are negligible.

Limit.—The junction with the Pendleside Series, P, is nowhere clearly exposed. D_{2-3} and P are seen together in the Bishopston road-cutting, but their relations cannot be determined with certainty, as both are weathered and crumbling and their steeply-dipping junction strikes along, and largely beneath, the road. The section suffices to show, however, that D_{2-3} with its abundant fauna is succeeded by a comparatively barren radiolarian-chert group (the base of P), the change, which is great and far-reaching both faunally and lithologically, being abrupt, if not marked by an unconformity (see p. 529). Of unconformity, however, there is no evidence, stratigraphical or palæontological, although the junction contrasts strongly, in its abruptness, with the gradual passage by alternation at Loughshinny.[1]

Typical exposures.—Oystermouth:—The Black Lias quarry (fig. 3, p. 492) affords an excellent section of a thickness of 86 feet of beds in the condition of 'black lias' from near the top of D_{2-3} downwards; the sequence is without notable lithological or faunal change, and only one limestone, the thickest (3 feet), is sufficiently pure to make lime. In Colts Hill northern quarry the lowest beds only are exposed. 'Black lias' also forms the intervening ridge on which Oystermouth Castle stands.

Bishopston:—In the cutting—chiefly along its south side—on the Clyne Common-Bishopston Valley road, the top of D_{2-3}, to a thickness of at least 45 feet,[2] is exposed in the condition of 'rottenstones.' The sequence is obscured by weathering and foundering, but has yielded a rich fauna, largely as moulds.

P = *POSIDONOMYA* Zone.

This zone is represented by the Pendleside Series, first recognized in Gower by Dr. Wheelton Hind.[3] He correlated, however, with this series not only the beds now under discussion, but also the D_{2-3} 'rottenstones.' The composite group, thus constituted, had previously been called 'Bishopston Beds' by De la Beche[4] and 'Gower Shales or Series' by Phillips.[5] As regards the beds above D_{2-3}, Dr. Hind's correlation has been confirmed[6] by the subsequent

---

[1] C. A. Matley & A. Vaughan, Q. J. G. S. vol. lxiv (1908) p. 413.

[2] Details are recorded by Mr. Tiddeman, Swansea Memoir, pp. 22, 24.

[3] Geol. Mag. 1902, p. 485; *ibid.* 1904, pp. 402, 585–87.

[4] Mem. Geol. Surv. vol. i (1846) pp. 133–34.

[5] 'Manual of Geology' 1855, pp. 169–70.

[6] Of the fauna quoted by him, *Glyphioceras diadema* (Beyrich) alone may be regarded as of zonal value; and confirmation is, therefore, important.

discovery in them of *Glyphioceras spirale* (Phill.)[1] and *Posidonomya becheri* Bronn (p. 552). The importance of distinguishing between the 'rottenstones' and the overlying beds has been recognized by the officers of the Geological Survey, who have included the latter in the Millstone Grit, the 'rottenstones' (as previously mentioned) being 'Upper Limestone Shales.'

Lithological sequence.—In descending order:—

2. Dark, well-laminated, non-calcareous shales, with some ironstone-nodules and thin sandstones; in the lower part with black cherts[2]; according to De la Beche,[3] there is a thin limestone (4 inches) in the middle. Very thick.
1. Radiolarian cherts[4] with interbedded shales, the cherts showing the fine dark and light stripes, due to thin lamination, frequent in radiolarian deposits, and the shales, also, well-laminated and non-calcareous, but soft and in part weathering to a chocolate colour. Under the microscope it is seen that the cherts are exceedingly fine-grained, and that the dark and light laminæ differ one from the other in grain and in the relative proportions of their organic and inorganic constituents, the latter chiefly the finest quartz-silt. Many of the laminæ are lenticular, some of them sharply so. Wavellite occurs along joints. The total thickness is slight, the group forming, as it were, basal beds to the shales above.

   Apparently, the series includes no recurrence of the fossiliferous limestones characteristic of the underlying Avonian.

Fauna.—2. Largely unfossiliferous, but some beds are crowded with thin-shelled goniatites[5] preserved as casts.

1. Of the abundant radiolaria and subordinate sponge-spicules in the cherts, the former correspond closely with Culm forms.[6] The shales are largely unfossiliferous, but some have yielded a few lamellibranchs (p. 551) and indeterminate plant-remains.

Thickness.—Unknown, though probably at least 1500 feet, as *Glyphioceras spirale* (Phill.) has been found in abundance at apparently that distance above the base. Of this amount probably much less than 50 feet belongs to the radiolarian-chert group.

Limits.—The radiolarian cherts, doubtless, pass up into Group 2; but the junction does not appear to be satisfactorily exposed, and no repetition of similar cherts above is known. The upper

---

[1] By Mr. J. Pringle of the Geological Survey, Swansea Memoir, pp. 25 & 30; the specimens, 'J. P. 1260, 1265–1276' in the Survey collection, were found in a stream-bank on Barland Common, 150 yards west of Old Castle.

[2] Swansea Memoir, p. 25.

[3] Mem. Geol. Surv. vol. i (1846) p. 133.

[4] Dr. Strahan has described in the Swansea Memoir, pp. 22–25, how the discovery by Dr. G. J. Hinde of the radiolarian origin of these cherts resulted from De la Beche's comparison of the beds with the cherts of Codden Hill. He appends Dr. Hinde's description of the microscopic characters of the rocks and their organisms.

[5] Swansea Memoir, pp. 25 & 30.

[6] Dr. G. J. Hinde in the Swansea Memoir, p. 25.

limit of Group 2 has not been determined, but is not conspicuous lithologically, as the succeeding beds, up to the Coal-Measures, are, also, largely shales.

Where examined.—Bishopston, north side of road-cutting:—the radiolarian cherts. Barland Common:—the shales (Group 2); the most complete section is now overgrown, but was described by De la Beche[1] and has been discussed by Dr. Strahan.[2]

(2) North-Western District.

The sequence of the Avonian rocks in North-Western Gower is similar on the whole to that in Eastern Gower, and attention will, therefore, be directed chiefly to the differences between the two districts. The *Cleistopora* Zone, however, is poorly exposed in the Eastern district, and is described in some detail.

Most of the zones were examined along Burry Pill, the banks of which, north and north-west of Cheriton, afford a fairly complete sequence from a horizon low in the *Zaphrentis* Zone up to the middle of D_1, and much of D_1 was, also, found well displayed in Tor-gro, a range of cliffs between Burry Pill and Landimore. The thicknesses, estimated from outcrop and dip, in these localities are stated in Table I (facing p. 505).

Cleistopora Zone,[3] K.—This zone, although not completely exposed, especially towards the top, probably corresponds exactly with the Lower Limestone Shales, the resemblance to the development in those parts of the South-Western Province where this relationship holds good being close. It consists in descending order of:—

		Thickness in feet.
Probably K_2.	4. Grey shales, with thin limestones containing crinoids and brachiopods; upper part not seen; total thickness probably between 250 feet and	300
K_1 or K_2.	3. Limestones, including fine-grained dark oolite; at least	30
Probably K_1.	2. Like 4 on the whole; with Km	150
	1. *Modiola* Phase, Km. Grey shales with ostracodal and oolitic limestones and a red hæmatitic limestone of *a*-type; quartzitic sandstone with modioliform lamellibranchs near the base.	
	Total ...... between	400 & 500

The characters and thicknesses of Groups 1–3 and of 200 feet of Group 4 were determined in the banks of a dingle, north-east of Fairyhill House; the total thickness of the zone was estimated from its outcrop at Cheriton.

The base of the zone, as in most parts of the South-Western

---

[1] Mem. Geol. Surv. vol. i (1846) pp. 133–34.

[2] Swansea Memoir, pp. 22 & 30; also fig. 2 (p. 23).

[3] The field-observations were made conjointly with my colleague, Mr. T. C. Cantrill. I gladly take this opportunity of thanking him for encouragement and advice at many stages throughout this work.

Province, is well-defined lithologically and, in a sense, palæontologically also, the unfossiliferous, 'continental' Upper Old Red Sandstone giving place, rapidly but conformably, to the fossiliferous marine Avonian. The junction, as exposed in the Fairyhill dingle and recorded, with details of the adjacent beds, in the West Gower Memoir (p. 8), is as follows. The top of the Upper Old Red Sandstone is a barren, red marl with limestone-nodules ('race').[1] The base of the Avonian is a grey, sandy limestone with limestone-fragments, some of which are red like the 'race' in the underlying marl, the rest being, doubtless, practically contemporaneous. In the matrix between the fragments are a few ostracods and ooliths, and the bed is followed immediately by the 'sandstone with modioliform lamellibranchs' previously mentioned. The junction of the Old Red with the Avonian is so sharp as to be clearly traceable in a microscope-slide [E. 5288, Geol. Surv. Colln.]; and though it partly owes its conspicuousness to the difference in colour between the beds above and below, this difference is but the outward sign of a fundamental change in the conditions of deposition, marine organisms appearing in the rocks immediately above. In Gower, it may be noted, the change (which is inferred to be conformable from a merging of the top of the Old Red into the Avonian) is almost abrupt, and has been accompanied by current-action, as is evident from the fragments at the junction; in some parts of the South-Western Province, on the contrary, as for instance in Pembrokeshire,[2] marine and continental conditions alternated for a space.

The junction of Km with Group 2 of K_1 and that of K_2 with Z do not appear to be exposed. The limestone-group (3) probably separates K_1 from K_2, for it is exactly similar, lithologically, to the limestone that affords the best boundary between these two subzones in Pembrokeshire.

Zaphrentis Zone, Z.—Cherts are found, though only now and then, above the group of limestones with cherts near the base of the zone.

Syringothyris Zone, C.—The *Caninia* Oolite is partly dolomitized at various horizons up to the top, the matrix between the ooliths being the material chiefly affected. In places, the rock has been partly silicified, the silica taking the form of numerous aggregates of microscopic quartz-crystals; unlike the dolomite, these replace ooliths and stop at the interstitial matrix.

The top of the Oolite is uneven, the irregularities reaching a depth of a foot or more. But the hollows are not in all cases simple depressions; some extend into the Oolite laterally and are overhung by roughly-horizontal tongues of it measuring up to a foot

---

[1] The red marl, to a thickness of 4 feet, rests upon unfossiliferous, pebbly, grey quartzite which is probably the top of the thick quartz-conglomerates that form the upper part of the Upper Old Red of Gower (West Gower Memoir, p. 5).

[2] 'Summary of Progress for 1908' Mem. Geol. Surv. 1909, pp. 35–36.

in length. Somewhat similar irregularities are known elsewhere in shallow-water deposits, and have been caused by distortion of originally evenly-bedded strata while still plastic, shortly after deposition. It is possible, therefore, that the *Caninia* Oolite, also, has been drawn out tangentially while in this condition, though by what agency is not apparent; in this case, however, it is equally possible that the irregularities are due to some slight subaërial corrosion prior to the deposition of C_2.

The basal layers of the *Modiola* phase of C_2, which follow the *Caninia* Oolite sharply and fill the hollows just described, are puckered in a fashion suggestive of parts of landscape-marble. At higher levels in the phase conglomeratic beds are rare in this district; and dolomite-mudstones appear to be restricted, as in parts of Pembrokeshire, to a buff-weathering, argillaceous group at the top. The fauna of the phase is devoid of standard forms, and a *Mitcheldeania*-like alga[1] (in minute fragments) is present; otherwise the fossils are those found in the Eastern District.

The standard limestones of C_2 differ considerably in character, though not in fauna—except in an absence or rarity of *Caninia*—from the same subzone in the Eastern District. The chief difference lies in an absence of contemporaneous dolomite in North-Western Gower, even the gasteropod-valves, which would be readily affected by 'contemporaneous' dolomitization, being wholly calcitic; further, the beds are more uniform in character, rather darker and less thickly-bedded than in the Eastern District. They thus approach the facies of the *Seminula* Zone of the outcrop north of the coalfield.

Note.—Along the east side of Burry Pill the zone has been extensively vein-dolomitized.

Seminula Zone, S.—The lower subzone, S_1, is similar on the whole to the underlying standard limestones of C_2, but includes, though rarely, thin calcite- or dolomite-mudstones and, possibly, a little dolomite that has 'contemporaneously' replaced limestone; chert is absent. The top of the subzone was not seen.

In the S_2-oolites, as in the *Caninia* Oolite, some ooliths have been replaced by aggregates of microscopic quartz-crystals; but dolomite is wanting. In the *Modiola* phase which forms the upper part of the subzone, mudstones, including 'chinastone-limestones' and nodular beds, appear to be better developed than in the Eastern District, and dolomite is wanting. The change to the standard conditions of Zone D at the close of the phase was rapid.

Dibunophyllum Zone, D.—The chief divergences in this part of the sequence from the development in Eastern Gower are (1) an absence of dolomite, as in C_2 and most of S; (2) the presence of a thick oolite at the base of D_1; and (3) the presence of D_2.

(1) The absence of dolomite is most noticeable where the material is known to be particularly susceptible to dolomitization; such

---

[1] By this expression is meant a calcareous alga with a minute, radially-columnar structure; such identification must suffice, until the revision of the genera promised by Prof. E. J. Garwood is published.

material is presented both by the valves of gasteropods and by the unrecrystallized part of pseudobreccias. The latter, with typical structure (see Pl. XXXVIII, fig. 2) and abundant foraminifera, are as widespread as in the Eastern District, but, like the gasteropod-valves, are in all cases devoid of dolomite. In connexion with pseudobreccias, it may be noted that one of the best exposures of the 'pitted' bedding-planes (p. 490) that characterize some of them may be observed in Tor-gro, Landimore. One such bedding-plane, dipping at a steep angle, which has been described by Dr. Strahan in the West Gower memoir, p. 12, is shown in Pl. XXXVIII, fig. 1. The incoming of *Cyrtina septosa* (Phill.), which varies in its horizontal distribution, is worth noting; in this district it first becomes abundant near the base of the pseudobreccias.

(2) The D_1-oolite, which is about 50 feet thick, is coarse-grained, like the band in the same position in Pembrokeshire. The lowest part is darker, more thinly-bedded and less oolitic than the rest; otherwise the contrast with the *Modiola* phase at the top of S_2, immediately below, is complete.

(3) D_2 has been recognized at Llanrhidian. In the top of the Main Limestone the highest bed exposed in the neighbourhood has yielded the following fauna[1]:—

Choneti-Productus.
Papilionaceous *Chonetes* or *Daviesiella.*
Martinia glabra (Mart.).
Martinia lineata (Mart.).
Productus corrugatus M'Coy.
Productus edelburgensis-latissimus.
Spirifer bisulcatus Sow.

The rock is a dark and bituminous, crinoidal limestone, rich in brachiopods; unfortunately it is seen to a thickness of only a few feet (in low crags 260 yards east of the church). It is underlain by light-grey, nodular limestones, probably pseudobreccias, which have yielded merely giganteid *Productus* and may belong either to D_1 or to D_2. Downwards in the sequence other beds are not seen for some distance, and upwards nothing is known until the radiolarian cherts[2] at the base of P are reached: it is uncertain, therefore, whether D_{2-3} is present in this district.

(3) South-Western District.

The structural features of this district, which lies between Rhossili and Port-Eynon Bays, are shown and described in the Geological Survey map and memoir.[3] Here we need only mention that, owing to a syncline in the promontory south-west of Rhossili, much of the sequence Z-C_1 is found along both the north-western and the southern sides of the promontory, and that it is repeated yet again near the Inner Head by an anticline ranging west-north-west through the gut between the mainland and the Worms-Head islets. The western extremity of the Worms-Head islets was not examined.

---

[1] Identified by Dr. Vaughan and preserved in the Geological Survey Collection (E. D. 891-906).

[2] Poorly exposed in a lane a furlong east of the crags of D_2-limestone.

[3] One-inch sheet 246 (Worms Head); West Gower Memoir, pp. 3, 12-16.

As in the case of North-Western Gower, attention will be paid chiefly to the differences between this district and those previously described.

Cleistopora Zone, K.—Probably equivalent to the Lower Limestone Shales. All the groups seen in North-Western Gower appear to be present, and in the following account are referred to under the same numbers as those on p. 496.

1. *Modiola* phase, Km. This group includes a 5-foot band of conglomerate (exposed north-west of Rhossili rocket-house) of red-brown quartz-pebbles, measuring up to half an inch in diameter, with larger pebbles of fossiliferous mudstone or shale, the whole in a matrix of calcareous sandstone which encloses, also, reddened and rounded crinoid-ossicles like those in limestones of α-type. The conglomerate is both overlain and underlain by ostracod-shales with limestones and sandstones, but probably lies near their base; the junction of those below with the underlying Upper Old Red Sandstone is not exposed. The thin limestones interbedded with the shales are chiefly of a type usual at this horizon, that is, most of them contain a mixed fauna of crinoids, brachiopods, ostracods, lamellibranchs, small *Bellerophon*-like gasteropods and *Orthoceras*, besides fragments of contemporaneous sediments, including phosphates.

2. As in Pembrokeshire, the standard part of K_1 commences with a group of quartzitic sandstones (Rhossili), and the parallelism is maintained in the shales immediately below Group 3, which, as exposed at the north-west foot of Hardings Down, are distinguished by the markedly nodular character of their interbedded limestones.

3. As in North-Western Gower (and Pembrokeshire); exposed at Hardings Down.

4. Not seen.

Zaphrentis Zone,[1] Z.—In South-Western Gower, Z consists largely of limestones, dolomites, though frequent, being subordinate. Shaly bands are found, but at considerable intervals, through much of the lower part of the zone: and cherts, with beekitized fossils, have a considerable upward range (beekite being abundant in the lowest beds—some part of Z_1—exposed in the anticline at Worms Head,[2] and cherts, with beekite, occurring for several hundred feet above).

As usual in this zone, the limestones are largely crinoidal and rather thinly-bedded, and the dolomites dark grey and finely crystalline. The fauna is tabulated on pp. 544–45.

---

[1] First recognized in this district by Dr. Gubbin & Dr. Vaughan, Proc. Bristol Nat. Soc. ser. 4, vol. i (1905) pp. 50–52, 54.

[2] The lowest beds in this anticline have been referred by Dr. Gubbin & Dr. Vaughan (*op. cit.* pp. 50 & 54) to Z_2 on insufficient evidence. Their horizon is probably lower than that of the lowest beds at Rhossili, rather than above as stated by those authors, and it is agreed that the Rhossili beds (*op. cit.* pp. 51 & 54) belong to Z_1. The beds at both places were once considered by myself to lie at the base of the zone (West Gower Memoir, p. 15), but a re-examination of the district, though leaving the age as Z_1 unquestioned, has thrown doubt on their basal position, especially as regards the beds at Rhossili.

The boundary between Z_1 and Z_2 was not located, but is evidently not marked by any striking lithological change; the top of Z_2, also, is not conspicuous, as nodular and argillaceous beds, though most characteristic of Horizon γ above, commence in the highest part of Z_2.

The most complete and accessible section lies between the core of the Worms-Head anticline, at a level somewhere in Z_1 (see preceding footnote), and the edge of the cliff at the Coastguard Station to the north-east, which exposes the top of the zone and a few yards of the overlying γ beds. Here at least 530 feet (a figure obtained largely by direct measurement) is exposed, but in this district the full thickness of the zone cannot be determined.

Horizon γ and *Syringothyris* Zone, C.—The chief points to be noticed in this part of the sequence are:—

(1) Horizon γ is well developed;
(2) The *Laminosa* Dolomites are but partly dolomitized, and contain cherts and beekitized fossils;
(3) There is no *Modiola* phase at the base of C_2;
(4) The facies of C_2 resembles that of the standard C_2-limestones of the Eastern District, not that of the North-Western District.

(1) Horizon γ consists of thinly bedded, nodular limestones with soft argillaceous partings; this character is most marked in the upper part. Fossils, especially corals, abound; they are magnificently displayed on extensive, weathered surfaces at Tears Point—the best Avonian collecting-ground in Gower, but unfortunately discovered too late for its fauna to be recorded.

The base of Horizon γ, defined as the level at which large Caninids first become frequent, may be placed, to facilitate recognition, at a rather marked argillaceous bed which reaches the sea at Tears Point. The summit was placed, arbitrarily, but merely for the purpose of measurement, at the lowest of the dolomites which are the feature of the overlying *Laminosa* Dolomites, for in the absence, so far as could be seen, of *Chonetes* cf. *comoides* (Sow.) from the *Laminosa* Dolomites, there did not appear to be any important faunal difference between this group and Horizon γ.

(2) The lower part of the *Laminosa* Dolomites (for thickness, see the table on p. 502) consists of about equal proportions of dolomites of the usual character and of unaltered limestones; the limestones are rich in corals, and contain also some crinoid-cups. The upper part is normal in its dolomitization, but includes occasional chert-nodules and beekitized fossils. The change at the top to the *Caninia* Oolite is rapid, that is, the thickness of dolomitized oolite at the junction is small, and so too in North-Western Gower.

(3) Standard C_2 limestones follow the *Caninia* Oolite immediately. Their basal bed is firmly welded to the somewhat uneven top of the latter, and contains small masses of oolite (the outcome, doubtless, of a little contemporaneous erosion), which are mixed with broken brachiopods, corals, etc., proper to C_2.

(4) The C_2 limestones are largely light-grey and thickly-bedded, and are less crinoidal than many parts of Z; probably fewer dolomites and gasteropod-beds are intercalated than in C_2 of

Eastern Gower. The subzone passes up insensibly into the similar limestones which form the lower part of S_1.

In the *Caninia* Oolite, it may be observed in passing, there are thick bands of fine-grained, non-oolitic material, some of which is foraminiferal, some comminuted-crinoidal; corals are more frequent near the top of the Oolite than at lower levels, those noticed being *Michelinia*, *Syringopora*, and a Clisiophyllid.

The thicknesses of the subdivisions of Horizon γ and C_1 vary somewhat, as may be seen from the accompanying table. The thickness of C_2 was obtained, with some uncertainty on account of faulting, only between Fall and Mewslade Bay; it probably lies between 280 and 350 feet.

Thicknesses in feet of Horizon γ and Subzone C_1 in South-Western Gower.

		Laminosa Dolomites.				
	γ	Lower part.	Upper part.	Total.	*Caninia* Oolite.	Total, $\gamma+C_1$.
Fall	120	80	60	140	160 (at least)	420
Inner Head...	135	115	90	205	130	470

The best exposures of Horizon γ and C are (1) the Inner Head islet, accessible for a limited time from the mainland by crossing the rocky isthmus at low tide:—the whole, except the top of C_2; (2) the cliff-top near Old Castle, Rhossili, where γ has yielded the fauna enumerated on p. 545, and the *Laminosa* Dolomites also are seen; (3) Tears Point and the cove called 'Fall' on the north:—γ and C_1; (4) the fine range of cliffs[1] between Fall and the bluff west of Overton Mere:—C_2 with much of S.

Seminula Zone,[2] S.—This zone has almost the same facies as in the Eastern District. The top appears, however, to be so lacking in rock-types characteristic of *Modiola* phases, that it is separated from the rest of S_2, not on its own merits, but for purposes of comparison with the *Modiola* phase on this horizon in other areas.

The general sequence, which has been determined more exactly than in Eastern Gower, is as follows, in descending order:—

S_2:—

3. *Modiola* phase. Evidenced merely by occasional 'pisolites.' The 'pisoliths' outwardly resemble those which are so abundant in the Eastern District, but include fragments of a *Mitcheldeania*-like alga. True calcite-mudstones, such as 'chinastone-limestones,' if

---

[1] Described by Dr. A. Strahan in the West Gower Memoir, pp. 12–13.

First recognized in this district by Dr. Gubbin & Dr. Vaughan, Proc. Bristol Nat. Soc. ser. 4, vol. i (1905) pp. 44–50, 54–56.

present, are rare; their place is, apparently, taken by limestones that are rather less fine-grained and contain an abundance of *Calcisphæra (?)* and foraminifera. These rocks and the 'pisolites' are interbedded with oolite like that of Group 2 below, their lower limit being unknown but probably quite indefinite. Upwards the change to Zone D with its characteristic fauna and sediments is comparatively rapid, the highest bed definitely assignable to S_2 being separated from the lowest undoubted D limestone—the oolite described on p. 504—by 24 feet of limestones of less determinate relations.

2. Chiefly light-grey, thickly-bedded oolites, many sparingly fossiliferous; some fine-grained limestones, composed of current-bedded organic detritus. At intervals occur dark, finely-crystalline dolomites, up to several feet thick, which, though in some cases markedly impersistent along the bedding, as already described by Dr. Strahan (West Gower Memoir, p. 13), are inferred, from their microscopic characters,[1] to owe their alteration to the influence of the Carboniferous sea. Near the base of the group the limestones contain sporadic, light-grey sponge-cherts, of concentric, alternately siliceous and calcareous zones. Thickness, including the *Modiola* phase above, between 820 and 870 feet.

1. Gasteropod-limestones,[2] dark, highly bituminous, and well-bedded; many of the gasteropods selectively dolomitized in the way described on p. 484; cherts and beekitized fossils. Thickness =120 feet.

S_1:—

2. Gasteropod-limestones, dark and continuous with those above, but on the whole more thinly-bedded, and separated from one another by soft shaly partings; highly fossiliferous (p. 547); beekite in fossils in the upper beds; some beds more or less dolomitized. Thickness =105 feet.

1. Limestones, similar to the underlying C_2 limestones; less fossiliferous than the beds above; little dolomite and no chert or shale. Thickness =115 feet.

The whole zone is exposed in the cliffs and shore near Port-Eynon Point, from the bluffs at the cliff-foot, west of Overton Mere,[3] where S_1 is finely displayed, eastwards to Sedgers Bank, where D comes in. S_1 and S_2 enter largely into the cliffs on the west, also, of Overton Mere, as far as Mewslade Bay.

---

[1] Similar to those of contemporaneous dolomites described in the Swansea Memoir, pp. 16–20 & pl. i, fig. 4.

[2] Included by Dr. Gubbin in S_1; the absence of *Caninia bristolensis* Vaughan has led to my placing this group in S_2.

[3] Details from this locality, especially of the gasteropod-beds, are recorded by Dr. Gubbin (Proc. Bristol Nat. Soc. ser. 4, vol. i, 1905, pp. 44–50), who has, however, greatly underestimated the thickness of S_2; the 'black calcareous sandstone' to which he refers on p. 47 is the dolomite in Group 2 of S_2, mentioned above.

Dibunophyllum Zone,[1] D.—The important feature of this zone in South-Western Gower is a strong development of D_2, a subzone which is unknown in Eastern Gower though present in the North-Western District.

The facies of D_1 differs in no important respect from that observed in Eastern Gower. An oolite, 7 feet thick, in part of the coarse type usual at this horizon, lies at or near the base. Some of the beds, including some pseudobreccias,[2] are dolomitized, the gasteropods showing the selective action previously mentioned.

In D_2 are placed the highest beds of the Main Limestone. The change of fauna in passing from D_1 to D_2 is not accompanied by any lithological change, so far as known, but pseudobreccias die out some distance above. The upper part of D_2 consists of various rock-types, including coarse oolite, coral-limestone, dark fine-grained bituminous limestone with black chert, dolomite, and pale limestone. Some of the latter occurs immediately below D_{2-3}, but is as pure as any other part of the Main Limestone, except for an abundance of pale chert. The change to D_{2-3}, faunal and lithological, is as rapid as in Eastern Gower.

D_{2-3} is equivalent to the Upper Limestone Shales, which are similar to the beds of the same name in Eastern Gower, except that they include, interbedded among the argillaceous limestones and shales, a few pure, pale limestones with chert, resembling some of the D_2 limestones. The correlation with D_{2-3} of Eastern Gower is discussed on pp. 551–52.

The top of the zone and its relations to the overlying P beds are not revealed.

The whole of D_1 and D_2, 600 feet in all, and a thickness of at least 150 feet of D_{2-3}, the latter folded, and much reddened by Triassic infiltration, crop out on the shore of Port-Eynon Bay. Better exposures of much of D_1 and D_2, with the faunas recorded on pp. 548–49, are obtained in quarries in the plateau above Port-Eynon Point; those in D_2 lie about a quarter of a mile south-south-west of Port-Eynon church.

Posidonomya Zone, P.—The development in this district is probably the same as in other parts of Gower. Radiolarian cherts are believed by Dr. Strahan[3] to crop out near Overton; and shales, grey or raddled, with the fauna enumerated on p. 552, are exposed in an old 'paint-mine' at Port Eynon described by the same author (*loc. cit.*). Black, evenly-bedded sponge-cherts do not appear to be exposed in the mine *in situ*; but, to judge by fragments in the overlying Triassic conglomerate, they do occur in the series. A single band, a few inches thick, of shale studded with crinoid-ossicles and now decalcified, emphasizes the rarity of such material above the *Dibunophyllum* Zone.

---

[1] First recognized in this district by Dr. Gubbin & Dr. Vaughan, Proc. Bristol Nat. Soc. ser. 4, vol. i (1905) pp. 43–44 & 56.

[2] These I described in the West Gower Memoir, p. 16, as 'without dolomite,' whereas some only are undolomitized.

[3] West Gower Memoir, p. 18.

To face p. 505.]

TS OF GOWER.

Zone, Subzone or Horizon.		**North-We**		
Posidonomya Zone. P.		As in the Eastern district, appar	ess. eet. han 50 feet.	As in the Easte
Dibunophyllum Zone. D.	D_{2-3}	Not known.	350 feet.	Much as in th intercalated, stones.
	D_2 or D_{1-2}	D_2 :—Limestones.	et.	D_2 :—Coral-, oo breccias; che
	D_1	Much as in the Eastern distri without dolomite.	450 feet.	Much as in the
Seminula Zone. S.	S_2	2. *Modiola* Phase:—Calcite-mud 'pisolites'; standard limes 1. Chiefly light-coloured oolit dolomite known.	t.	3. *Modiola* Ph among sta 1 & 2. Chiefly cherts near limestones
	S_1	Rather dark limestones, with calcite- or dolomite-mudsto 'contemporaneous' dolomite chert.		2. Gasteropod-l little chert 1. Thickly-bec dolomite.
Syringothyris Zone. C.	C_2	2. Similar to S_1, but without m or dolomite. 1. *Modiola* Phase;—Much as Eastern district.	et. t.	Similar to gro developed at
	C_1	2. *Caninia* Oolite. 1 *Laminosa* Dolomites.	et.	2. *Caninia* Ool 1. *Laminosa* I undolomit
	γ	Not recognized.		Chiefly nodular
Zaphrentis Zone Z.	Z_2	Similar to the *Laminosa* Dolom		Limestones wit part, to a h Gower.
	Z_1	Much as in the Eastern district.		
	β	Not recognized.		
Cleistopora Zone K.		Lower Limestone Shales:—2–4 shales with thin limestones; oolitic limestone, probably b K_1 and K_2 1. *Modiola* Phase, Km. Grey with ostracod-limestones; lin of α-type.		Lower Limestc but probably 1. *Modiola* Ph shales; a
		(Passage)		
Devonian.		U		

(4) Tabulated Synopses of the Sequence.

Table I embodies the chief features of the developments in the three districts of Gower, together with the thicknesses, which are also shown graphically in fig. 4 (p. 506). In both table and figure the Eastern District is placed between the two others because, as will be seen, it has relations with both. The differences between the different developments, of which more will be said later, might not be regarded as of importance, were it not that each development could be matched elsewhere in the South-Western Province.

Table II embodies the features common to much or all of the area, and may be regarded as typical of much of the South-Western Province.

TABLE II.—SYNOPSIS OF THE LITHOLOGICAL SEQUENCE IN GOWER AS A WHOLE (GENERALIZED FROM TABLE I).

Zone or Subzone.		
P.		2. Chiefly dark non-calcareous shales.
		1. Radiolarian cherts.
D.	D_{2-3}[1]	'Black lias':—soft-weathering, argillaceous limestones with shales and cherts.
	D_2 or D_{1-2}	Limestones, including pseudobreccias.
	D	Chiefly pseudobreccias; thin coal[2] or coals.
S.	S_2	2. *Modiola* phase, characterized especially by 'pisolites.'
		1. Chiefly oolites.
	C_2+S_1	2. Limestones of various types.
		1. *Modiola* phase,[3] characterized especially by abundant calcite- and dolomite-mudstones.
C.	C_1	2. *Caninia* Oolite.
		1. *Laminosa* Dolomites (replacements of crinoidal limestones).
Z.		Crinoidal dolomites and limestones; cherts near the base.
K.[4]		2. Grey shales with thin limestones; a thick oolitic limestone, probably between K_1 & K_2.
		1. *Modiola* phase, Km, characterized especially by limestones of *a* type.
Devonian.		Upper Old Red Sandstone.

Note:—K is equivalent, probably exactly, to the Lower Limestone Shales; the sequence, Z to D_2 inclusive, is termed 'Main Limestone' by the Geological Survey; D_{2-3} is termed Upper Limestone Shales; and P is included with the Millstone Grit.

---

[1] Not known in the North-Western District.

[2] Not known in the South-Western District.

[3] Not developed in the South-Western District.

[4] K is best known in the North-Western District, but there is no reason to believe that the development is different elsewhere.

[Quart. Journ. Geol. Soc., Nov. 1911.

TABLE I.—SYNOPSIS OF THE LITHOLOGICAL SEQUENCE IN DIFFERENT PARTS OF GOWER.

Zone, Subzone or Horizon.		North-Western District.		Eastern District.		South-Western District.	
			Thickness.		*Thickness.*		*Thickness.*
POSIDONOMYA ZONE. P.		As in the Eastern district, apparently.	Unknown.	2. Chiefly dark, non-calcareous shales; some black sponge-cherts in the lower part. 1. Radiolarian cherts with shales; wavellite.	At least 1500 feet. Probably less than 50 feet.	As in the Eastern district, apparently.	Unknown.
DIBUNOPHYLLUM ZONE. D	D_{2-3}	Not known.	Probably less than 300 feet.	'Black lias':—soft-weathering, argillaceous limestones and shales, with sponge-cherts and some dolomite; wavellite near the top.	Between 175 & 350 feet.	Much as in the Eastern district, but with some intercalated, non-argillaceous, cherty limestones.	At least 150 feet.
	D_2 or D_{1-2}	D_2:—Limestones.		D_{1-2}:—Limestones, including pseudobreccias; dolomite.	At most 120 feet.	D_2:—Coral-, oolitic, and other limestones; pseudobreccias; cherts; dolomite.	About 200 feet.
	D_1	Much as in the Eastern district, but without dolomite.		Chiefly pseudobreccias, generally dolomitic; 'pitted' surfaces; thin coal with underclay.	Between 400 & 450 feet.	Much as in the Eastern district (coal not known).	About 400 feet.
SEMINULA ZONE. *S.*	S_2	2. *Modiola* Phase:—Calcite-mudstones; 'pisolites'; standard limestones. 1. Chiefly light-coloured oolites; no dolomite known.	At most 800 feet.	*Modiola* Phase:—Calcite-mudstones; 'pisolites'; standard limestones; dolomite. The development of S up to the *Modiola* Phase is much as in the South-Western district.	About 1250 feet.	3. *Modiola* Phase:—Poor; a few 'pisolites' among standard limestones; dolomite. 1 & 2. Chiefly light oolite with zoned sponge-cherts near its base; some cherty gasteropod-limestones below; dolomite.	About 1000 feet.
	S_1	Rather dark limestones, with a rare calcite- or dolomite-mudstone or 'contemporaneous' dolomite; no chert.				2. Gasteropod-limestones; shaly partings and a little chert; dolomite. 1. Thickly-bedded, pale limestones; little dolomite.	220 feet.
SYRINGOTHYRIS ZONE. C.	C_2	2. Similar to S_1, but without mudstone or dolomite. 1. *Modiola* Phase;—Much as in the Eastern district.	Between 230 and 280 feet. 45 feet.	2. Much as in the South-Western district. 1. *Modiola* Phase (wanting at Longland Bay):—Chiefly calcite-mudstones; dolomite.	200 to 350 feet. 16 to 20 feet.	Similar to group 1 of S_1. (No *Modiola* Phase developed at the base.)	Probably between 280 & 350 feet.
	C_1	2. *Caninia* Oolite. 1 *Laminosa* Dolomites.	100 feet. About 520 feet.	2. *Caninia* Oolite. 1. *Laminosa* Dolomites; few undolomitized (crinoidal) limestones.	70 to 160 feet. 320 feet.	2. *Caninia* Oolite. 1. *Laminosa* Dolomites, the lower part half undolomitized; occasional cherts.	130 to 160 feet. 140 to 200 feet.
	γ	Not recognized.		Not recognized.		Chiefly nodular, argillaceous limestones.	120 to 135 feet.
ZAPHRENTIS ZONE Z.	Z_2	Similar to the *Laminosa* Dolomites.		Similar to the *Laminosa* Dolomites.		Limestones with dolomites; cherts in the lower part, to a higher horizon than elsewhere in Gower.	At least 530 feet.
	Z_1	Much as in the Eastern district.		Dolomites, with crinoidal limestones in the lower part; cherts towards the base.	150 feet.		
	β	Not recognized.		Crinoidal limestones.		Not recognized.	
CLEISTOPORA ZONE K.		Lower Limestone Shales:—2–4. Grey shales with thin limestones; a thick oolitic limestone, probably between K_1 and K_2 1. *Modiola* Phase, Km. Grey shales with ostracod-limestones; limestone of α-type. (Passage)	Between 400 and 500 feet.	Probably the Lower Limestone Shales, which are barely exposed.	Unknown.	Lower Limestone Shales:—2–4. Little exposed, but probably as in North-Western Gower. 1. *Modiola* Phase, Km. Chiefly grey ostracod-shales; a quartz-conglomerate.	Unknown. Unknown.
Devonian.		**Upper Old Red Sandstone.**					

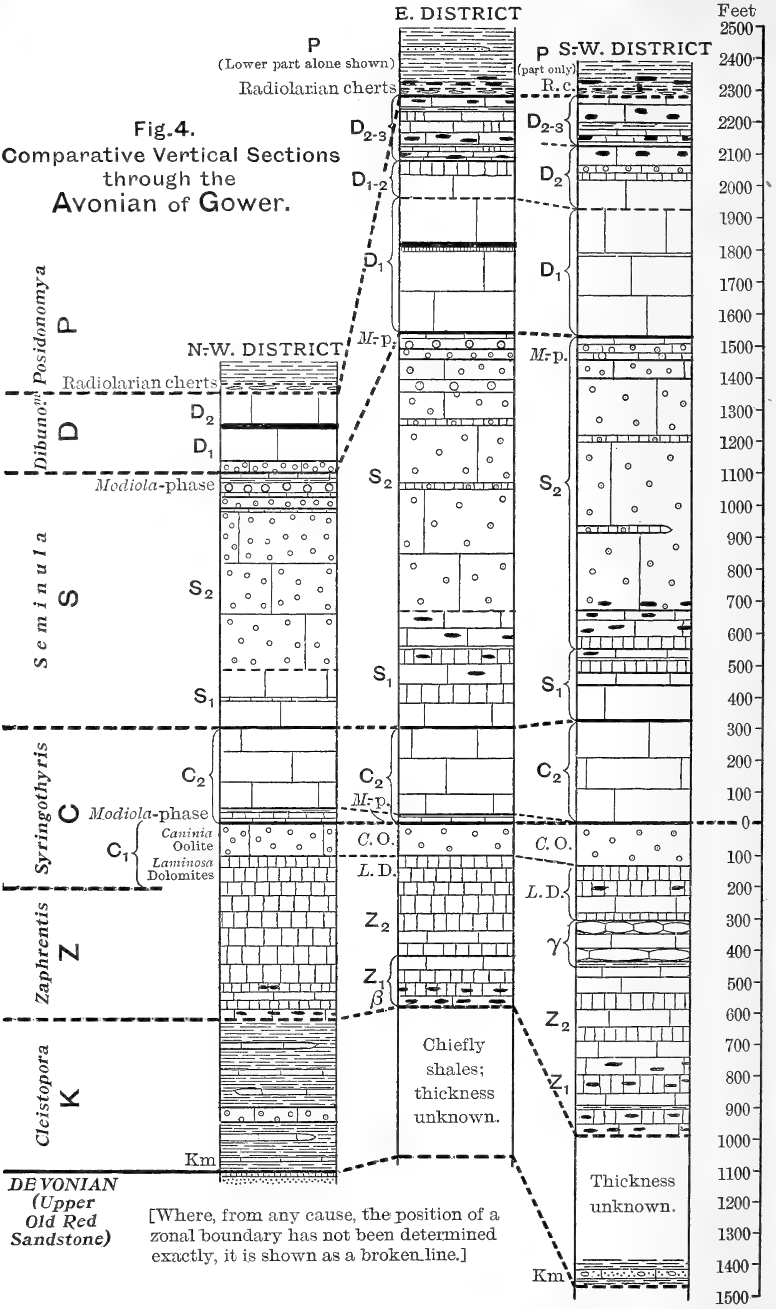


Fig. 4. Comparative Vertical Sections through the Avonian of Gower.

[Where, from any cause, the position of a zonal boundary has not been determined exactly, it is shown as a broken line.]

III. Note on the Pseudobreccias of the D-Zone
[E. E. L. D.].

The following observations relate to the pseudobreccias of Gower, where these rocks are peculiar to the *Dibunophyllum* Zone and at that level are extensively developed. While to some extent supplementing Mr. Tiddeman's description,[1] this note deals more particularly with the question of origin, which is of interest on account of the resemblance of the rocks to true breccias, and also because other nodular, foraminiferal limestones, such as some of the bands in the Chalk, may owe their structure to the same cause. It may be mentioned that the explanation of the structure of pseudobreccias, here advanced, has suggested itself to Mr. J. A. Howe also, in the course of a comprehensive study that he is making of these and other limestones.

The structure in question, the outward appearance of which may be gathered from Pl. XXXVIII, fig. 2, appears at first sight to be due to the incorporation of angular fragments of rather dark limestone, of various sizes up to a diameter of several inches, in a ground-mass which is limestone in some places, and dolomite in others, but is always lighter in colour and more argillaceous than the 'fragments,'[2] sometimes markedly so. The greatest contrast is presented where the 'ground-mass' is dolomite, as the latter forms a rather coarsely-crystalline, pale-grey mosaic.[3] We may first, however, consider the undolomitized examples.

'Fragments' and 'ground-mass' vary in their relative proportions, but as a rule are approximately equal, and the latter occurs characteristically as meandrine tracts enclosing the former. In no pseudobreccia has it been possible to distinguish bands differing one from the other in the size or abundance of their included 'fragments.' The same fauna, a standard marine assemblage, is found in the 'fragments' as in the 'ground-mass.'

Microscopic examination shows that the matrix of the fossils in both 'fragments' and 'ground-mass' is a consolidated 'mud,' consisting essentially of finely-divided calcite and containing, as a rule, a notable quantity of foraminifera.[4] Furthermore, such examination shows that the outlines of the 'fragments' are not sharp and well-defined like those of true fragments, but that their matrix shades off into the matrix of the 'ground-mass.' On this account largely, and also in view of other considerations which will be adduced, it is inferred that the rocks are not

---

[1] Swansea Memoir, p. 10.

[2] See analysis by Mr. E. G. Radley, Swansea Memoir, p. 13.

[3] A dolomitized example is figured in the Swansea Memoir, pl. i, fig. 1.

[4] The following have been identified in microscope-sections by Dr. R. L. Sherlock:—'Callencroft Quarry, Mumbles [E 5000]: very rich in foraminifera, chiefly Endothyræ, such as *Endothyra bowmani* Phillips, *Endothyra* sp., and *Textularia* sp. (either *gibbosa* d'Orb. or *eximia* Eichw.).—Oxwich [E 5001]: *Endothyra* sp. (small form).'

really fragmental. Ultimately, doubtless, they owe their structure in part to their composition,[1] but the proximate cause of it alone concerns us here.

Before passing to this subject, however, it should be remarked that Dr. Hume connects the nodular structure of parts of the Chalk with current-action.[2] A complete comparison of nodular chalks with pseudobreccias has not yet been made, but it is known that some of the former closely resemble the latter. It is possible that in the clay with limestone-rubble, into which occasional pseudobreccias pass laterally (p. 490), the rubble, which resembles the 'fragments' of pseudobreccias proper, but is sharply separable from its clay-groundmass, has been more or less rearranged by currents, after originating in a patchy recrystallization (and segregation) of calcareous mud in the manner presently to be described. There is no reason, however, to believe that the 'fragments' in the pseudobreccias proper have also been washed up and redeposited; and it remains to be seen whether all nodular chalks show evidence of current-action, or whether some are not pseudobreccias.

As contradicting the view that the 'fragments' in the Gower pseudobreccias are derived, and have been incorporated in their present condition, may be adduced the fact that occasionally some are continuous one with the other and partly enclose 'groundmass,' thus losing their resemblance to fragments. It may be suggested, however, that the 'fragments' in these rocks are true fragments of contemporaneous sediments, which, unrecrystallized at the time of their incorporation, have lost all trace of their limiting surfaces through later recrystallization of themselves and some of the surrounding ground-mass. Apart from the absence from the pseudobreccias of any sign of current-action in either a sorting or a banding of their constituents, no evidence of a truly fragmental origin has been detected in any of the numerous 'fragments' that have been examined, and the suggestion takes no account of the fact that, so far as known, the pseudobrecciated structure is confined to foraminiferal limestones.

To turn to the proximate cause of the pseudobrecciated structure, the features whereby the matrix in the 'fragments' differs from that in the 'ground-mass' are, in addition to its less argillaceous character, mentioned above: (1) that it is invariably rather more crystalline, though still fine-grained and obviously a slightly recrystallized mud; and (2) that it is often, possibly always, more foraminiferal. Both features are illustrated by Pl. XXXIX, in which, indeed, hardly any foraminifera are seen in the dense 'ground-mass.' (The 'fragments' are the light areas with irregular boundaries along the top, bottom and left-hand margins of the field.)

---

[1] Rocks similar in structure to the pseudobreccias of Gower are known in other regions, in the same and in other formations, but all appear to be foraminiferal. Many foraminiferal limestones, however, are not pseudobreccias, whence it is obvious that other conditions, besides a suitable composition, have been necessary for the production of the distinctive structure.

[2] Proc. Geol. Assoc. vol. xiii (1894–95) p. 230.

Confining our attention at present to the first feature, it is concluded that a muddy matrix has undergone partial recrystallization, as it were into irregular clots, and thus, by differentiation, quite possibly from a homogeneous state, given rise both to the 'fragments'—the recrystallized parts, and the 'ground-mass'—the less crystalline residue. This local recrystallization is inferred, for several reasons, to have taken place shortly after the deposition of the mud. Its peculiar patchiness, in which it differs strongly from late recrystallizations, and its widespread occurrence on the same horizon (D)[1] are most readily explicable on this view. Probably the best reason, however, is that, in Gower, as we shall see, many pseudobreccias have been dolomitized after recrystallization—but while still within the influence of the Avonian sea[2]; such a view postulates an early age for the recrystallization. The latter, therefore, appears to be analogous to the early recrystallization known to affect recent calcareous muds,[3] but why it assumed a patchy character is unknown.

The other features of the pseudobreccias would result directly from a patchy and early recrystallization of a calcareous mud. Recrystallization implies deposition of calcite, and would probably be accompanied by segregation of that mineral and, in a still soft matrix, extrusion of impurity into the unrecrystallized parts. This action would account for the excess of argillaceous matter in the 'ground-mass.' Furthermore, delicate calcareous bodies like foraminifera would tend to disappear from the unrecrystallized parts, to balance, by their dissolution, the deposition of calcite in the recrystallizing areas.

But, whatever be the ultimate nature of the 'fragments,' their more coarsely crystalline structure in comparison with the 'ground-mass' has given rise to secondary features of much interest. They appear darker in hand-specimens, on account of their greater translucency. Again,—and this is of far more importance,—they offer a greater resistance to chemical change than the 'ground-mass,' in accordance with the general rule that in calcitic rocks such resistance is proportional, *cœteris paribus*, to the coarseness of the crystalline structure. The difference is shown in a variety of ways. The 'fragments,' which may be almost invisible on a fresh surface, often project boldly on weathered faces. Occasionally, it is found that the 'ground-mass' has recrystallized at some late date completely to coarse calcite-mosaic, but the 'fragments' included in this mosaic are still unaltered. The difference, however, between the two kinds of material is shown most conspicuously by the difference in their susceptibility to

---

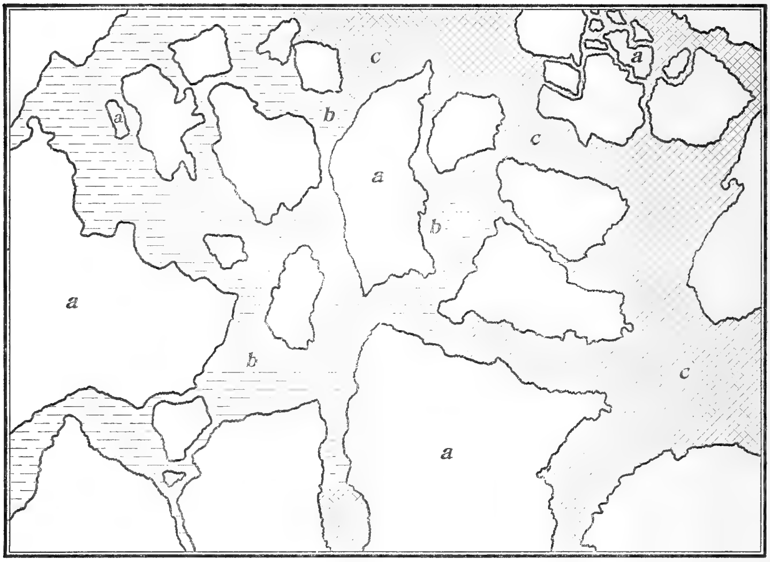
[1] Pseudobreccias are frequent in D, not only in Gower but also in many other areas both within and without the South-Western Province.

[2] This view as to the age of the dolomitization is based not only on the original evidence cited in the Swansea Memoir, p. 14, but also on various facts which have come to light since.

[3] See, for instance, E. W. Skeats, Bull. Mus. Comp. Zool. (Harvard) vol. xlii (1903) pp. 105–18, figs. 2 & 4–6.

dolomitization by the waters of the Avonian sea. (Dolomitization due to clearly-later percolation, it may be noted in passing, has affected both materials equally.) In fact, the difference between the 'ground-mass' and the 'fragments' in this respect is so great as to suggest that at the period of dolomitization the former was still unconsolidated and readily permeable, as well as more unstable. In many pseudobreccias and for long distances in them it has been completely altered, though, as a rule, the whole of the enclosed 'fragments' have been but little affected. It has thus, by determining the paths of dolomitization, led to a marked accentuation of the pseudobrecciated structure. In many dolomitized pseudobreccias, as in the example figured in the Swansea Memoir, pl. i, fig. 1, the 'ground-mass' has been so completely replaced by dolomite-mosaic in which its proper structures have been lost, that the original nature of the material replaced by the dolomite would be open to doubt, were it not that in other such pseudobreccias dolomitization has been incomplete, and wholly absent from parts

Fig. 5.—*Diagram showing the relation of the dolomite, in a partly dolomitized pseudobreccia, to unrecrystallized calcite (see p. 511). Natural size.*



[*a*, *a* represent 'fragments,' consisting of recrystallized calcite; *b*, *b*, tracts of 'ground-mass,' consisting of unrecrystallized calcite; and *c*, *c*, dolomite. The limit of the dolomite is generally sharp against the 'fragments,' but against the unrecrystallized calcite it is too indefinite, as a rule, to be shown properly in a diagram.]

of others again. The latter, one of which is represented diagrammatically by fig. 5 (p. 510), show clearly that the paths followed by the dolomitization have been the tracts of unrecrystallized 'ground-mass.' Pl. XXXIX, taken from the junction of a dolomitized with an undolomitized portion of a pseudobreccia, shows that the dolomite has developed freely in the dense 'ground-mass,' partly as isolated rhombohedra, partly as a band of clustering crystals, but that it has been excluded from the more crystalline 'fragments.' (The diagonal cross seen in many of the rhombohedra is probably due to inclusions of the argillaceous impurity in the 'ground-mass.')

Dolomitized pseudobreccias, such as that figured in the Swansea Memoir, resemble true breccias more closely than do the unaltered rocks, owing to the great contrast in them between the sharply-defined 'fragments' of dark, fine-grained limestone and the enveloping pale-grey, rather coarsely-crystalline dolomite. Also, their structure is more conspicuous, whether on unweathered faces, or in cliffs, where they often become cavernous through the dissolution of their 'fragments.' Consequently in Gower, where they abound along the southern coast, they have attracted more attention ; but, as we have now seen, their dolomitization has not been the primary cause of their peculiar structure—it has merely brought into prominence an earlier recrystallization.

IV. Note on Lagoon-Phases and the Origin of Radiolarian Cherts [E. E. L. D.].

(1) Introduction and Definition.

By a lagoon-phase is meant a group of rocks, the characters and development of which show that it has been deposited in a coastal area, of wide extent both parallel and at right-angles to the coast, but so extremely shallow as to have been, in effect, isolated from the neighbouring though deeper parts of the sea, and thus to have become the site of peculiar types of sediment and fauna.[1]

A lagoon-area as thus defined is shown in section, at right angles

---

[1] It has been thought better to adopt the word 'lagoon' and to speak of such an area as that defined above as a lagoon-area, rather than to coin a new expression, because the conditions obtaining in lagoons, as defined in the 'Century Dictionary' (London, 1899), must approximate closely to those which it is desired to connote. According to this authority, a lagoon is primarily 'an area of shallow water, or even of marshy land, bordering on the sea, and usually separated from the region of deeper water outside by a belt of sand or of sand-dunes, more or less changeable in position.' Though there is no evidence that subaërial barriers, such as dunes or coral-reefs, have existed in the case of the lagoon-areas with which we shall deal, possibly because the chances are against their having been preserved, exposed, and correctly interpreted, they are evidently not essential features of lagoons. Further, several formations which are lagoon-phases as above defined, such as the Solenhofen Slate, are described by Prof. J. Walther and others as having been deposited in shallow lagoons.

to the trend of the coast, in fig. 6. Lagoon-phases are regarded as coastal deposits, and the lagoon-area, consequently, is shown in the figure as a coastal shelf, for reasons which appear later (pp. 525–28). The area is represented as bordered by rapidly deepening water, to accord with the general profile of recent coastal shelves.

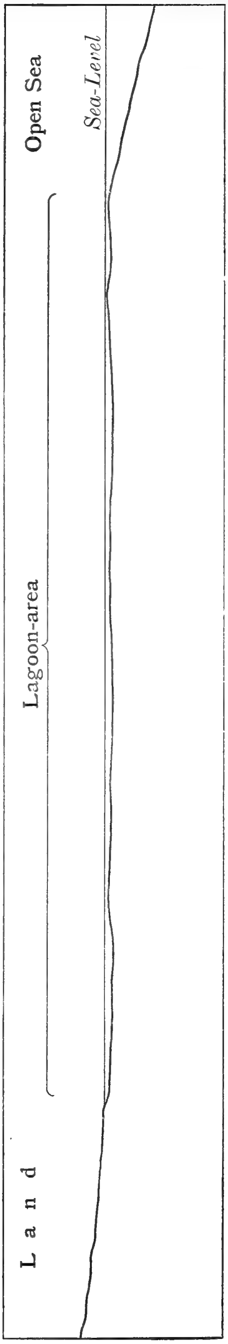


Fig. 6.—*Ideal section across a lagoon-area, at right angles to the coast.*

[The slopes throughout, both terrestrial and submarine, are exaggerated.]

That extremely-shallow marine areas, such as are here postulated, have formerly existed is beyond question, for the deposits in some cases may be interpreted without hesitation. Under the names of '*Modiola* and *Posidonomya* phases' some of these deposits, of Avonian age and calcareous facies, have already been described by Dr. Vaughan,[1] and the object of this note is, partly to bring out the distinctive characters of these phases, partly to extend the concept to rocks of cherty facies. Lagoon-phases, therefore, would include both *Modiola* and *Posidonomya* phases and equally shallow deposits of other ages and facies.

But, although lagoon-areas have undoubtedly existed, it is probable that their extreme shallowness and wide extent together would not sufficiently account for the general absence from them of strong currents, which, as we shall see, has been their distinguishing feature. Apparently the rise and fall of the tide, which, if considerable, would inhibit lagoon-conditions on an open coast, has been either so small as to be negligible, or has been rendered inoperative by subaërial barriers, which may have included thickets of vegetation such as those of mangrove-swamps, along the margins bordering deeper water.

---

[1] These are tabulated by him in Table II of his report on the faunal succession in the Avonian, Rep. Brit. Assoc. (Winnipeg) 1909, p. 190; reference will presently be made to his description of the development of these phases in the Avon section.

(2) The *Modiola* Phases—Calcareous Lagoon-Phases—of Gower.

Introduction.—The Carboniferous succession in Gower includes four lagoon-phases, namely, Km at the base of K, the base of (C_2+S_1),[1] the top of S_2, and the radiolarian cherts at the base of P. The chief features of each of the first three, which are calcareous in facies, are set out in Tables III & V (pp. 514 & 526), the deposits characteristic of shallow waters being distinguished from intercalated ordinary sediments where, as is generally the case, the latter exist. The fourth phase, which differs from the others in being cherty, will be discussed separately, as an origin at a totally different depth has been ascribed to rocks elsewhere possessing closely similar characters. All four phases have been recognized at other places in the South-Western Province and some of them elsewhere also; the information in the tables concerning the Bristol area has been extracted from Dr. Vaughan's accounts,[2] and that about Pembrokeshire has been obtained during the progress of the Geological Survey.[3] No attempt, however, will be made to give full particulars of the geographical extent of any phase.

Distinctive features of the *Modiola* phases.—We may now learn from Table III in what way *Modiola* phases differ from ordinary marine formations; from the interpretation of their distinctive features, which will follow, it will appear why they may be styled 'lagoon-phases.'

On the one hand, all the Gower *Modiola* phases exhibit, at one place or another, but not necessarily everywhere, unmistakable shallow-water characters which are shown to some extent, also, by ordinary shallow-water deposits (Table III, 1 & 2). In the first and third phases there are, likewise, many intercalations of ordinary rock-types (Table III, 4), due to the interruptions of lagoon-conditions by more normal ones mentioned on p. 518.

On the other hand, they all include, also, one or more rock-types (Table III, 3) which, in a fairly shallow-water marine series, such as the Avonian, are confined either to *Modiola* phases or to merely occasional beds in the shallow-water parts of the sequence. Some of these distinctive rock-types (namely, limestones of α type and purple and green shales) appear to point directly to deposition in shallow, isolated, coastal areas, and, therefore, will be considered first; the other group to be discussed here—mudstones and shales characterized by an exceedingly fine grain,—which is far more important than the first group on account of its more general occurrence, resembles, rather, deep-sea deposits.

---

[1] By this expression is meant the group consisting of subzones C_2 and S_1.

[2] Q. J. G. S. vol. lxi (1905) p. 181 (cited thus: 'Bristol paper,' p. ...); and, in the case of the Avon section, Proc. Bristol Nat. Soc. ser. 4, vol. i (1906) pp. 74–168 (cited thus: 'Avon,' p. ...).

[3] 'The Country around Haverfordwest' and 'The Country around Pembroke' (Mems. Geol. Surv.); in preparation.

Table III.—The *Modiola* Phases—Calcareous Lagoon-Phases—represented in Gower.

	Km, the *Modiola* Phase at the base of K.	The *Modiola* Phase at the base of $(C_2 + S_1)$.	The *Modiola* Phase at the top of S_2.
1. Shallow-water characters: faunal and floral.	Some beds yield little, except:—lamellibranchs, such as *Modiola* and *Sanguinolites*; *Spirorbis (?)*; abundant ostracods, such as *Cytherella*.[1]	Almost all the beds are unfossiliferous or yield[4] only:—lamellibranchs, e. g. *Sanguinolites (?)*; *Spirorbis*-like annelids; abundant ostracods, e. g. *Cytherella*; *Mitcheldeania* or similar algæ (Forest of Dean; North-Western Gower, etc.).	Some beds, such as the 'chinastone-limestones,' are unfossiliferous, or yield only *Spirorbis*-like annelids. Beds with many fragments of a *Mitcheldeania*-like alga (South-Western Gower).
2. Shallow-water characters: lithological.[2]	Some beds show a brecciation in which the fragments are but slightly separated[6] ('Avon,' p. 100). Beds with fragments of contemporaneous sediments. Presence of pure oolite of very fine grain (Pembrokeshire, etc.). Packing of ostracod-valves within one another by long-continued drifting.[3]	Some beds show a brecciation in which the fragments are but slightly separated[6] (Gower, etc.). Beds with fragments of contemporaneous sediments. Presence of pure oolites of very fine grain. Presence of 'pisolite' (Eastern Gower).	Beds with fragments of contemporaneous sediments. Presence of 'pisolites' (Gower, etc.). Presence of pure oolites.
3. Deposits distinguishing the *Modiola* phases from other shallow-water marine formations.	Calcite-mudstones, slabby to nodular ('Avon,' pp. 100, 103; etc.). Limestones of *α* type. Purple and green shales (Pembrokeshire).	Abundant calcite-mudstones and dolomite-mudstones: homogeneous (for instance, 'chinastone-limestones') to finely-laminated; a little of the latter in North-Western Gower crumpled as in landscape-marble.	Calcite-mudstones, chiefly homogeneous ('chinastone-limestones'). Limestones with the structure of landscape-marble ('Avon,' pp. 91–93; Sodbury[5]).
4. Marine sediments of standard types included within the *Modiola* phases.	Always present, so far as known; consisting of: (1) intercalated limestones and sandstones with an abundant brachiopod-and-crinoid fauna,—frequent. (2) fine conglomerate (South-Western Gower, etc.).	Very rare; for example, a thin limestone-parting with crinoids at Caswell Bay (Eastern Gower).	Always present, so far as known; consisting of:— (1) intercalated limestones with abundant corals and brachiopods (often of few species),—abundant. (2) grit-bands (Sodbury[5]).

Note.—Features of general occurrence are not followed by the name of a locality.

---

[1] This fauna in its entirety is known only from the Avon; at most localities some members are missing.

[2] Some characters found in the *Modiola* phases, though to be expected in shallow-water deposits, may occur through a considerable range of depth. They include:—the presence of plant-fragments (in the first and second phases); of contemporaneous dolomites (in the second and third phases); and of quartz-sand (in the matrix of breccias in the second phase in Eastern Gower).

[3] First noticed in Purbeck limestone, and explained, by Mr. F. Chapman, Proc. Geol. Assoc. vol. xix (1905–6) p. 284 & pl. v, fig. 2.

[4] The complete fauna is known only near Pembroke Dock; at most localities some members are missing.

[5] A. Vaughan, Bristol paper, p. 209.

[6] The cause of this brecciation *in situ* (p. 486) has not been determined, but that of an apparently similar phenomenon in certain beds of *Modiola*-phase type in the Scottish Carboniferous is, Mr. R. G. Carruthers tells me, suncracking and consequent flaking; and it may be added that cracks, vertical or irregular, having in section the appearance of suncracks and filled with the matrix of the overlying limestone, have been found in a calcite-mudstone in the phase at the base of C_2 in Gower.

Limestones of a type.—Limestones of a type, named after the well-known Bryozoa Bed, Horizon a,[1] of the Avon, consist largely of crinoid-ossicles and dendroid bryozoa, broken and rounded by rolling and reddened with hæmatite. Hæmatite may appear, also, in the matrix and in the coatings of ooliths, but the characteristic feature of the rocks is the relation of the iron-oxide to the fossils; it infills organisms, such as bryozoa, that possessed open cavities, and picks out the trabecular structure of the crinoid-ossicles.[2]

The significance of limestones of a type lies in this—that their distribution and lithological characters, details of which are reserved for another communication, all point to the conclusions that they have received their iron-content (apart from secondary enrichment) at the time of their deposition, and that the iron-compound has been, from the first, in the condition of oxide and probably, as now, in that of hæmatite. These views, though differing directly from those of Prof. Cayeux as to the origin of a Devonian (Eifelian) hæmatite from the Ardennes which has the characteristic structure of limestones of a type,[3] are in full agreement with the conclusions of C. H. Smyth, Junr.,[4] and others[5] regarding the period of introduction and primary nature of the hæmatite in the well-known Clinton (Silurian) iron-ore of the United States, an ore that also contains a quantity of rolled bryozoan and crinoidal débris, infilled and picked out with hæmatite.

The contemporaneous deposition, in a sedimentary formation unassociated with igneous rocks, of a considerable quantity of an iron compound,—and especially of hæmatite, if that were the original condition of the iron-ore,—appears to be incompatible with open-sea conditions and to demand comparative isolation and proximity to land. Limestones of a type are, therefore, directly suggestive of deposition in isolated, coastal areas[6]; but, at the same time, their fauna, which consists largely of standard forms, and the broken and rolled state of their constituents, indicate conditions which, though shallow, depart from those—of abnormal fauna and gentle sedimentation, as we shall see—most characteristic of lagoon-phases.

Purple and green shales.—Purple and green shales that owe their colour to conditions of deposition are of much more restricted

---

[1] Described by A. Vaughan, Proc. Bristol Nat. Soc. ser. 4, vol. i (1906) p. 99.

[2] See a microphotograph of a limestone of a type in 'The Country around Newport' Mem. Geol. Surv. 2nd ed. (1909) pl. fig. 1.

[3] 'Les Minerais de Fer Oolithique de France' fasc. i (1909) pp. 225–26: the structure in quesion is beautifully figured in this volume. I am greatly indebted to the courtesy of Prof. Cayeux for the use of some of his material.

[4] Zeitschr. f. prakt. Geol. vol. ii (1894) pp. 304–13.

[5] For instance, E. F. Burchard & E. C. Eckel in 'Iron Ores, &c. of the Birmingham District, Alabama' Bull. U.S. Geol. Surv. 400 (1910) pp. 28 & 40.

[6] This view, also, agrees with that of the American observers mentioned above, who regard the Clinton ore as deposited in shallow bays and lagoons (see, for example, *op. supra cit.* p. 40).

occurrence in the Avonian than the preceding rock-type, being recorded only from Km in a few localities. Their unusual colour points to deposition in comparative isolation. Furthermore, the fact that in other formations they are often associated with continental deposits suggests proximity to land; but it remains to be seen whether they have been formed under other conditions of isolation as well.

Calcite-mudstones and similar rock-types.—The second of the groups of rock-types distinctive of *Modiola* phases is much more widespread than either of the preceding types; its members occur in all such phases as are known and at many places in each. They are compact[1] limestones, dolomites, and argillaceous rocks which, under the microscope, are seen to be composed, essentially, of exceedingly fine-grained, calcareous (that is, either calcitic or dolomitic), argillaceous, and siliceous material, and evidently represent, in most cases at least, consolidated muds[2] of various compositions. For this reason, the calcareous members will be spoken of as calcite-mudstones or dolomite-mudstones,[3] in order to distinguish them from limestones or dolomites of standard types The calcite-mudstones include the rocks known as 'chinastone-limestones,' so called because their compactness and white weathered surface impart to them a porcellanous appearance. Most of the rocks are evenly bedded, but some have concretionary forms. The calcite- and dolomite-mudstones are either homogeneous and more or less conchoïdal in fracture, or are laminated and present a slabby or platy fracture; the laminæ, which, in places, are extremely thin, are either persistent or lenticular—wedge-bedded on a minute scale. The homogeneous and the laminated types are equally fine in grain. Similarly, the argillaceous rocks may be either clay-mudstones,—rocks to which the term 'mudstone' is ordinarily applied—, shales, or paper-shales. Under the microscope the bedding in the case of the laminated mudstones, calcareous or otherwise, is clearly shown, even in the absence of fossils, by the layers, which differ greatly one from the other in composition and appearance; but in sections of the non-laminated mudstones it cannot, as a rule, be made out without the help of fossils. Where largely calcareous, such mudstones might be taken for travertine; but that they have been deposited in the form of mud, whether detrital or chemically precipitated, is shown by the fact that, where the material has partly

---

[1] That is, amorphous-looking, and, in fact, often called 'amorphous' though the constituent grains possess crystal-structure.

[2] This statement is based on an examination, still in progress, of various limestones and dolomites that occur in *Modiola* phases. It remains to be seen whether it is universally true of the compact layers; in some cases, as, for example, that of landscape-marbles, an origin as travertine by direct accretion from solution has previously been suggested.

[3] It is possible that the dolomite-mudstones are calcite-mudstones dolomitized without change of structure, but the balance of evidence at present available suggests that they have been deposited as dolomite-mud.

filled a hollow fossil, its surface against the residual space, originally empty, is flat—in fact, a bedding-plane.

Those mudstones in which calcite or dolomite is predominant are the most important, because they differ conspicuously from rocks formed under standard conditions. It is true that standard limestones frequently contain a considerable proportion of calcite-mud,—so far dolomite-mud has not been detected in them; included with it in such limestones, however, are the remains of open-sea organisms, for example, crinoids, brachiopods, and corals. Limestones which are simply hardened calcite-muds, or contain merely the forms enumerated opposite '1. Shallow-water characters' in Table III (p. 514), appear to be confined in marine series to the distinct groups of strata (*Modiola* phases) under discussion, or, if found among standard deposits, to an occasional occurrence in shallow-water formations.

For the origin of the calcareous portion of the muds we do not need to look beyond the detrition and disintegration of organisms, both within and without the area of actual deposition, and also, to some extent, of contemporaneously-formed[1] limestones (oolites, etc.) and dolomites, fragments of which are found in the interbedded breccias. It is possible, however, that some, or even much, of the mud has been chemically precipitated. But, in any case, the uniform fineness of grain,—which characterizes the intermingled terrigenous material also,—compels a conclusion of much importance, namely, that the sedimentation of the mudstones was exceedingly gentle.

Conditions of deposition of the *Modiola* phases.—Hence we see that the notable feature of the *Modiola* phases represented in Gower is in each an anomalous association of characters. On the one hand, some of the latter indicate deposition in shallow water: in fact, signs of marked current-action, such as the inclusion of contemporaneous fragments, are to be found, in most localities, at some part of each phase. On the other hand, the texture of the rocks affords repeated evidence of the gentlest sedimentation.

The explanation of the anomaly is to be sought in peculiar conditions of deposition. It is conceived that, as the area of deposition of each phase was shallow, and extended far, both parallel and at right angles to the Avonian coast (Table V, p. 526), under certain circumstances the outer part of the area would protect the inner from waves and strong currents, even in the absence of subaërial barriers along the outer margin,—and of the existence of such barriers, as previously mentioned, we have no evidence. The necessary attendant circumstances would be that tides were at a minimum—to which

---

[1] Some of the mud may have been derived in part from older limestones also, but to an extremely small extent, probably, as regards material deposited in Gower; the phase in C_2+S_1 may, however, owe more of its material to such sources in those parts of the South-Western Province where it rests upon older Avonian limestones unconformably.

condition a steep slope of the sea-bottom down from the shallow area would be favourable—, and that the shallowness of the sea was extreme.

In other words, each phase was deposited in a shallow area of sufficient extent to constitute, under conditions of minimal tides and excessive shallowness, a great series of lagoons as defined in the footnote on p. 511. In such a lagoon-area the pools would catch the finest material, both that of local origin and the part that was brought into the area from various sources outside,[1] and there wafted about by gentle currents. Slightly stronger currents would lead to the washing-up and incorporation of fragments of contemporaneous sediments; and the area would be liable to invasion at times by waters depositing standard rock-types. Such invasions might result either from some deepening of the whole lagoon-area, or from the temporary demolition of a bar—whether subaërial or merely submarine. At other times, local emersion would probably occur and be followed by cracking of the mud. In this way the brecciation *in situ* may have arisen.

Further, as some such conditions of deposition as are here outlined alone explain satisfactorily the whole of those lithological features of the Gower *Modiola* phases that are discussed above, we conclude that the strata of these phases have been deposited under such conditions and are, accordingly, representative of 'lagoon-phases.'

Landscape-marbles and 'pisolites.'—Some remarkable rock-types, however, which appear to be confined to *Modiola* phases, do not receive complete explanation, although their features are not inconsistent with genesis in a lagoon-area; consequently their discussion is deferred. Of these rock-types the chief may be called 'landscape-marbles,' as they reproduce the essential features of the Rhætic bed of that name, itself part of a *Modiola* phase. Landscape-marble is conspicuous in the top of S_2, the so-called 'concretionary beds,' in the neighbourhood of Bristol and elsewhere; and one of its features is developed on a minute scale at the base of C_2 in North-Western Gower. The so-called 'pisolites' of C_2 and S_2 must have also required for their formation special conditions as well as shallowness.

Faunal characteristics of the *Modiola* phases.—The lagoon-area concept bears the same relation to the faunal peculiarities of the phases as it does to the lithological features; it explains most of them, and accords with the rest. The mudstones, which must be regarded as deposited under conditions of greatest isolation, are also most restricted in their faunal contents, being in many cases unfossiliferous, and in most of the others yielding, whatever be their horizon, only a special, phasal fauna. Of this fauna the members of most general occurrence are certain lamellibranchs, especially *Modiola* and *Sanguinolites*, *Spirorbis*-like annelids, as also ostracods

---

[1] The colouring-material of the purple and green shales and of the limestones of *a* type almost certainly came directly from the land, but much other mud, including part of the calcite, may have entered from the seaward margin.

and *Calcisphæra (?)* in abundance; but at many places one or two members only are found. The lack of standard fossils in the mudstones is striking in the case of the phases that we are considering: for the latter occur in a formation, the Avonian, dominated by crinoids and other open-sea forms. A few mudstones, however, as, for instance, some at the top of S_2, contain many individuals (though but few species) of brachiopods, especially *Seminula*, that lived under standard conditions also. Again, the proximity of the postulated lagoon-areas to the open sea with its abundant fauna, and their liability to invasion, account for the abundance of standard forms in the intercalations of ordinary rock-types, which are frequent in some phases (Km and the top of S_2). The S_2 'pisolites,' also, have been laid down in disturbed waters, and yield an ordinary marine fauna. It may be noted that, in the phase in C_2+S_1, intercalations yielding open-sea forms are extremely rare.

The phasal fauna is essentially shallow-water, but its poverty and peculiar nature demand for full explanation something more than mere shallowness. The isolated position in which the mudstones must have been deposited—whether separated from deeper water simply by extensive shallows or by actual barriers—would be favourable either, under certain circumstances, to an increase of salinity, or, near a river, to a freshening of the waters. In either case much of the standard fauna would be excluded. Some ostracods, like their modern representatives, doubtless could endure, and even thrive under, such adverse conditions. The same appears to have been true of other organisms also. Thus, although lagoon-conditions would favour the accumulation of plankton, including *Calcisphæra (?)*, simply on account of its ease of transport from the open sea outside the lagoon-area, the fact that some of the calcite-mudstones contain an abundance of *Calcisphæra (?)*, but fewer or no foraminifera, whereas standard Avonian limestones (including those deposited in shallow water) yield these two groups of organisms in inverse ratio, suggests that *Calcisphæra (?)* throve in the lagoons.

But, whether due to more than mere shallowness or not, the characteristic feature of the calcite-mudstones, the most distinctive rocks of the calcareous lagoon-phases of Gower, is barrenness or a peculiar fauna, rich in individuals but not in species, which, though but poorly represented in intervening standard deposits, is remarkably recurrent, as regards genera and wider groups, in different phases.

(3) The Radiolarian Phase—Cherty Lagoon-Phase—of Gower.

Modes of origin of radiolarian deposits.—The fourth lagoon-phase, that at the base of P, consists of radiolarian cherts with interbedded, laminated shales which have yielded a few lamellibranchs and plant-fragments. As, however, many radiolarian rocks have, in consequence of the classic work of Dr. G.

J. Hinde, been regarded as deep-sea deposits (on account of their exceedingly fine-grained texture as well as the abundance of radiolaria in some recent deep-sea deposits), before proceeding we must show why we conclude that the Gower cherts, which are similar in both fauna and texture, have been formed under diametrically different conditions. This is the more necessary, on account of the weight attaching to the opinion of Dr. Hinde, as well as the importance of the further conclusions based by other geologists on his work.

The way has been prepared by many observers, who have shown that radiolarian rocks have not necessarily been deposited at the depths at which the radiolarian oozes above-mentioned are found; in the case of some there is strong evidence of a shallow-water origin. Thus, at Garn-bica in Carmarthenshire, on the same horizon as the Gower cherts similar rocks have been found by Mr. T. C. Cantrill and described by Dr. G. J. Hinde[1] which, though of finer grain, if anything, than the Gower cherts, may be inferred to have been deposited in shallow waters, on account of their occurrence as a thin, conformable group between two shallow-water formations—the Rottenstone Beds at the top of the Carboniferous Limestone below and the Millstone Grit above.

As may be gathered from the conclusions of Dr. Hinde & Mr. Fox as to the conditions of deposition of the Lower Culm radiolarian rocks of Devon,[2] of Prof. David & Mr. Pittman in the case of the similar Devonian rocks of New South Wales,[3] and of others, as well as from a remark of Prof. Watts in discussing the Australian example (*op. cit.* p. 64), the most characteristic feature, next to their fauna, of all radiolarian rocks is their freedom from any, except the finest, terrigenous material. This character is irreconcilable with an origin in shallow waters of an open sea. A clue, however, to conditions of semi-isolated though shallow deposition is afforded by the calcite-mudstones of the *Modiola* phases previously described. These rocks, though differing from them in composition, resemble radiolarian cherts in being, essentially, exceedingly fine-grained.[4] Further, some contain an abundance of unicellular plankton—*Calcisphæra (?)*. We may, therefore, find parallels for the peculiar features of radiolarian cherts among those of the calcite-mudstones of *Modiola* phases. These mudstones have, undoubtedly, been deposited in shallow waters, but the chief feature wherein they resemble radiolarian cherts, namely their fine grain, is anomalous in shallow-water deposits; as we have seen on pp. 517–18, it is necessary to suppose that the waters were under lagoon-conditions. Similarly, it is concluded that those radiolarian rocks that appear, from independent evidence, to have been formed in shallow waters, owe their

---

[1] 'The Country around Ammanford' Mem. Geol. Surv. 1907, pp. 72-76.

[2] Q. J. G. S. vol. li (1895) p. 662.

[3] *Ibid.* vol. lv (1899) p. 36.

[4] The terrigenous material in the mudstones is as fine-grained as the calcareous.

anomalous characters to deposition under lagoon-conditions.[1]

In the application of this general principle to particular cases, before a rock-group that satisfies the conditions of exceedingly fine texture and shallow-water origin is regarded as a lagoon-phase, its geographical extent should, if possible, be determined, and for the following reason. For the maintenance of lagoon-conditions it appears to be necessary that the shallow area be of wide extent (see 'Conditions of Deposition of the *Modiola* Phases,' pp. 517–18); and certainly their size has been a feature of the areas of deposition of those lagoon-phases that are known.

The Gower radiolarian cherts a lagoon-phase.—In the case of the radiolarian-chert group of Gower and Carmarthenshire, a shallow-water origin is inferred from the stratigraphical evidence cited above, and accords with the presence, in interbedded shales, of lamellibranchs (p. 551) known elsewhere only from shallow-water formations. Also, the group has a wide geographic extent: it crops out in Carmarthenshire at a considerable distance from Gower, in a direction at right angles to the trend of the Avonian coast; and is known through much of South Pembrokeshire, in a direction from Gower parallel to that coast. Consequently, we conclude that it constitutes a lagoon-phase, and, in essentials, differs from *Modiola* phases merely in consisting of the remains of siliceous instead of calcareous organisms, in addition to fine-grained sediment. For contrast it will, occasionally, be convenient to speak of it as a 'radiolarian phase.'

Although this conclusion rests primarily on the evidence cited above, it is confirmed by other features of the radiolarian cherts on this horizon. The first is the fine, sharply-defined lamination which is conspicuous in these, as in other, radiolarian cherts and imparts to them a striped appearance. The laminæ differ considerably one from the other: for instance, in the proportion and nature of their detrital material. Further, many of the laminæ in the Gower cherts are strongly lenticular, that is, wedge-bedded. The sharply-varying composition and the impersistence of the laminæ point to the constant play of gentle currents laden with various, but always fine, sediments. These features, therefore, are to be expected in deposits formed under the lagoon-conditions previously described, and, as a fact, are found in many, including the finest, rock-types of *Modiola* phases, but they do not accord with a deep-sea origin—the only logical alternative to an origin in lagoon-areas in the case of most radiolarian cherts.

---

[1] Radiolaria are found at the present day at all depths, in greatest abundance in the plankton. Though they swarm in open seas, the environment in some lagoon-areas, also, would be favourable to their increase if the salinity were not appreciably higher than that of average sea-water,—a condition which would be realized in the proximity of a river (p. 525). Their accumulation in lagoon-areas would be further promoted by their ease of transport from the open sea outside.

In one respect, however, the radiolarian cherts differ from all the *Modiola* phases of Gower,—they are devoid of included fragments of contemporaneous sediments.

On the other hand, further confirmatory evidence is yielded by the black Pendleside or *Posidonomya* Limestones of the Midlands and elsewhere. These rocks include the horizon of the Gower cherts and appear, from their peculiar characters, to have been deposited in lagoon-areas[1]; their occurrence over a wide extent of country testifies to a wide prevalence of lagoon-conditions on that horizon. Some of them contain an abundance of bodies which, Mr. Howe suggests with much hesitation, may be radiolaria (*op. cit.* p. 400); and in North Devon similar limestones, there known as the 'Venn Limestones,' are associated with radiolarian cherts which, as we shall presently see, probably include the horizon of the radiolarian cherts of Gower.

The Culm radiolarian cherts also a lagoon-phase.—We may now tabulate (Table IV, p. 523) the features of the radiolarian phase, including some which have been observed in the Devon radiolarian cherts, for comparison with those of the Gower *Modiola* phases. The radiolarian nature of the Lower Culm cherts (the Codden-Hill Beds) of Devon was long ago pointed out by Dr. Hinde & Mr. Fox,[2] who, however, for the reasons mentioned above, regarded them as deep-sea deposits, the associated Venn Limestones being considered as but somewhat shallower in origin.[3] Dr. Wheelton Hind has more recently shown[4] that these limestones, together with part, at least, of the cherts, are correlative with the Pendleside Series. The correlation of the radiolarian cherts and overlying beds of Gower with the same Series tends to confirm the view, suggested by De la Beche and strengthened by recent work of the Geological Survey,[5] that the radiolarian cherts of the two areas occur at one horizon.[6] (It is probable, of course, that the Devon cherts, which are much thicker than those of Gower, include other horizons also.) The close similarity[7] of the cherts of Devon and Gower is such strong presumptive evidence of community of origin, that it is difficult to believe that those of the one area have been formed in comparatively deep water and those of the other in shallows. And my own observations (see Table IV, p. 523) in

---

[1] With this view Mr. J. A. Howe, who first adequately described the rocks, Q. J. G. S. vol. lvii (1901) p. 399, tells me that he agrees.

[2] Q. J. G. S. vol. li (1895) p. 609.

[3] Of the shallow-water origin of the Venn Limestones there can, however, be no doubt.

[4] Geol. Mag. dec. 5, vol. i (1904) p. 392.

[5] See A. Strahan, Swansea Memoir, pp. 22–25.

[6] It may be useful here to mention that the horizon in Gower with which the Codden-Hill Beds are homotaxial is that of the radiolarian cherts, not of the underlying beds with trilobites and brachiopods referred to by Dr. Wheelton Hind (Geol. Mag. 1904, p. 402); the latter belong to D_{2-3}.

[7] The similarity has been remarked by others, including Dr. G. J. Hinde (Swansea Memoir, p. 25), and extends to the fine lamination and minute wedge-bedding that I have adduced as evidence against a deep-sea origin for the Gower cherts.

TABLE IV.—THE RADIOLARIAN PHASE AT THE BASE OF P.

Characters unusual in deep-sea deposits or directly suggestive of an origin in shallow water:—	(1) Faunal.[1]	The sole macroscopic organisms of some interbedded shales are the lamellibranchs (unbroken) mentioned on p. 551, known elsewhere only from shallow-water formations (Gower).
	(2) Stratigraphical and Lithological.	Occurrence as a thin group conformably intercalated between two shallow-water formations,—the Rottenstone Beds and the Millstone Grit (Carmarthenshire [4]). Presence of intercalated beds of 'culm' (coal), several inches thick (Barnstaple [2]). Lenticular, wedge-bedding of many laminæ, the latter sharply defined and differing considerably in composition one from the other.
Characters distinguishing the phase from ordinary shallow-water marine formations.		Fine grain of the terrigenous material. Abundance of radiolaria.
Ordinary sediments included within the phase.		Very rare, if existent: for, although some beds resemble ordinary shales and silts and, in Devon, some contain corals, etc.,[3] radiolaria appear to be abundant throughout and no coarse sediment is known.
Relations to the beds:—	(1) below	Conformably resting upon the Rottenstone Beds in Carmarthenshire.[4] Not known with certainty in Gower, Pembrokeshire, or North-Western Devon.[5]
	(2) above	Sharp, but conformable, change to the Millstone Grit in Carmarthenshire.[4] Not known with certainty in Gower, where the group gives place to shales, apparently without recurrences of radiolarian cherts. Not known with certainty in North-Western Devon.
Development in	(1) Bristol area ...	Absent.
	(2) Gower	Present throughout (and to the north in Carmarthenshire).
	(3) outcrops south of the Pembrokeshire coalfield.	Present throughout, except in the southernmost (Bosheston) outcrop.
	(4) North-Western Devon.	Present throughout[6]; thickness, and probably duration also, much greater than in South Wales.

Note.—Features of general occurrence are not followed by the name of a locality.

[1] The fauna of the Devon development, as recorded by various authors, contains no forms which need be supposed to have lived at great depths. For lists see G. J. Hinde & H. Fox, *op. cit.*,—all orders; H. Woodward, Geol. Mag. 1902, p. 481,—trilobites; Wheelton Hind, Geol. Mag. 1904, p. 398,—all orders; A. Vaughan, Geol. Mag. 1904, p. 531,—brachiopods and corals.

[2] First brought to my notice by Mr. J. G. Hamling.

[3] G. J. Hinde & H. Fox, Q. J. G. S. vol. li (1895) pp. 617, 643 *et seqq.*

[4] T. C. Cantrill in 'The Country around Ammanford' Mem. Geol. Surv. 1907, p. 75; and in conversation.

[5] The Devonian and Lower Culm of Fremington Pill, Barnstaple, said by De la Beche to pass one into the other ('Rep Geol. Cornwall, Devon, & West Somerset' Mem. Geol. Surv. 1839, p. 103), appear at present to be confined to isolated exposures affording no evidence on the question.

[6] G. J. Hinde & H. Fox, *op. supra cit.*

the Barnstaple district of North Devon,[1] so far as they go, suggest that the cherts cropping out there are lagoon-deposits rather than those of a fairly deep sea. Consequently, as we need consider only these two alternatives, it is concluded that the Carboniferous radiolarian cherts of Devon, which continue through a wide extent of the West Country, constitute a lagoon-phase. This conclusion is not impugned by any of the known features of these rocks in the rest of their outcrops. Various particulars are given in the comprehensive work of Hinde & Fox, and those that bear on the question are mentioned in Table IV (p. 523). There is, however, much to be learnt concerning this highly interesting group, and it is well that a detailed examination of the Lower Culm and Upper Devonian has been undertaken by my colleague, Mr. H. Dewey.

(4) Meaning of the Difference between the *Modiola* Phases and the Radiolarian Phase of Gower.

Although the radiolarian phase of Gower appears to have been deposited under the same conditions of depth as the *Modiola* phases, in facies it presents a great contrast. Each phase, however, reflects the character of the fauna of the sea adjacent to the lagoon-area in which it was formed, as the terrigenous material is, typically, similar in all; the difference resolves itself, therefore, into one between the facies of the contiguous open-sea fauna.

The open sea during the *Modiola* phases was rich in forms possessing calcareous skeletons and giving rise by detrition to much calcareous mud; some of this, doubtless, passed into the lagoon-areas with fine terrigenous material, to form, with the detritus of the indigenous fauna and, possibly, calcareous material chemically precipitated, the characteristic mudstones. But the radiolarian rocks were formed at a time (the commencement of P) when, in the South-Western Province, the sea underwent a great and persistent change in character. Calcareous organisms disappeared almost completely from that province, being chiefly represented throughout P and higher parts of the Carboniferous by thin-shelled goniatites and lamellibranchs. Siliceous forms, however, assumed greater relative importance, both in the ground-living fauna,—sponge-spicules being noticeable in the radiolarian cherts and at some higher horizons themselves forming cherts,—and among the free-swimming groups, where radiolaria became conspicuous.

But, although it is evident that in our area the sea from the commencement of P onwards was inimical to so rich a calcareous fauna as it had, up to that time, supported, yet not to a siliceous one, we do not know what precisely was the change in its character; for apparently that effect on its fauna might result from any one of several changes, such as a diminution in its soluble calcium-

---

[1] I take this opportunity of thanking Mr. J. G. Hamling, F.G.S., most heartily for placing his extensive knowledge of this district at my disposal.

content, or a reduction of temperature.[1] Neither its muddiness nor its probable shallowness would account for the faunal change, as similar influences had previously had no such effect, even when acting in conjunction, as during Km. But, whatever may have been the nature of the change in the sea, its radical character and the wide extent of the area affected point to an important change in the physiography of the region. Further, there is reason to believe that the change in the sea accompanied a marked increase in the influence of the waters from a neighbouring river (p. 539). And that radiolaria may abound in an area under such influence appears to be shown by their occurrence in quantity in the Lower Culm of Eastern Thuringia and the Vogtland, which is regarded, from the abundance of land-plants that it contains and for other reasons, as having been deposited in a muddy sea near the mouths of rivers.[2]

(5) Topographical Position of Lagoon-Areas.

That the areas of deposition of the *Modiola* phases of Gower were situated, probably in each case, immediately between the coast of the Avonian sea, which lay to the north throughout the South-Western Province, and the open water may be inferred from the following details, partly outlined in Table V, 2, p. 526. In arriving at this conclusion, true overlap of a phase by conformable higher beds is accepted as evidence that the lagoon-area in which that phase has been deposited has been limited by a shore-line along the line of overlap; while lateral replacement by ordinary marine sediments is accepted as evidence of the deeper-water limit of the area. For this reason a lagoon-area has been defined (p. 512) as essentially coastal.

The lagoon-phase at the base of K in Pembrokeshire overlaps the conformable Upper Old Red Sandstone in a northerly direction, and is itself in turn overlapped by conformable higher beds, which then rest directly upon Lower Old Red Sandstone or upon still older rocks. The deeper-water limit, also, of the lagoon-area appears to be reached in that county: for, at Freshwater West in the southernmost outcrop, the Upper Old Red Sandstone is followed immediately by ordinary marine sediments in which no lagoon-deposits have yet been found.

The lagoon-phase at the base of C_2+S_1 in Pembrokeshire succeeds the *Caninia* Oolite conformably south of West Williamston, but at that place an unconformity develops at its base. The proximity of the lagoon-area to a shore-line, thus suggested, appears to have persisted throughout the phase, for at Pendine

---

[1] L. W. Collet, 'Les Dépôts marins' Paris, 1908, pp. 10–22 & 219.

[2] J. Lehder, Neues Jahrb. Beilage-Band xxii (1906) pp. 79–80, 111.

TABLE V.—RELATIONS AND GEOGRAPHICAL EXTENT OF THE CALCAREOUS LAGOON-PHASES REPRESENTED IN GOWER.

	Km, the lagoon-phase at the base of K.	*The lagoon-phase at the base of $C_2 + S_1$.*	*The lagoon-phase at the top of S_2.*
1. Relations to the beds:— (1) below.	Generally conformable on Upper Old Red Sandstone, but in places (Carew, Pem.) unconformable on Lower Old Red Sandstone.	Generally conformable on *Caninia* Oolite, but in places unconformable on *Caninia* Oolite (West Williamston, Pem.[3]) or lower horizons (Pendine, Carm.[4]; etc.).	Conformable and intercalated with standard S_2 oolites.
(2) above.	Sharp change to standard deposits of K_1 age ('Avon,' p. 98; etc.[1]).	Abrupt change,[5] in places with some contemporaneous erosion, to standard deposits of C_2 or S_1 age.	Rapid change to standard deposits which form the base of D_1.
2. Development[8] in (1) the Bristol area and the Mendips, — eastern part of the South-Western Province.	Present throughout.[2]	Thick, extending to the base of S_1, in the north (Avon, etc.[6]). Thin, forming the base of C_2, at Weston-super-Mare. Absent in the south (Mendips).	Present throughout,—maximum at Sodbury.[7]
(2) Gower,—central part of the South-Western Province.	Probably present throughout.	Thin, forming the base of C_2, in North-Western & Eastern Gower. Absent in South-Western Gower.	Present throughout, but barely developed in South-Western Gower.
(3) Outcrops south of the Pembrokeshire coal-field,—western part of the South-Western Province.	Recognized throughout, except at Freshwater West on the southernmost outcrop.	Thin, forming the base of C_2, in northern outcrops (West Williamston; Tenby). Absent in outcrops south of Tenby.	Present throughout, but poorly developed in the southernmost (St. Gowan's Head) outcrop.

---

[1] The change is said by Dr. Vaughan (*loc. cit.*) to be 'much sharper in the Avon sequence than in any other part of the South-Western Province,' but has been found to be equally sharp in Pembrokeshire.

[2] A. Vaughan, Bristol paper, pp. 188 *et seqq.*; T. F. Sibly, Q. J. G. S. vol. lxii (1906) p. 327 [Mendips].

[3] 'The Country around Haverfordwest' Mem. Geol. Surv., in the press.

[4] At Pendine C_2 and S_1 are absent, and the lagoon-phase commences and ends at the base of S_2 (see pp. 527–28).

[5] In the Avon district (Bristol paper, pp. 194–95; Avon paper, pp. 94–95) there is less contrast than at most places between this phase and the succeeding deposit; but evidently much of the whole of C_2 and S there present has been formed under lagoon-conditions.

[6] A. Vaughan, Bristol paper, p. 222 [Tytherington]; p. 207 [Sodbury]; p. 194 [Avon].

[7] *Ibid.* p. 210.

[8] At present we know too little of the development outside the areas considered to make its discussion profitable.

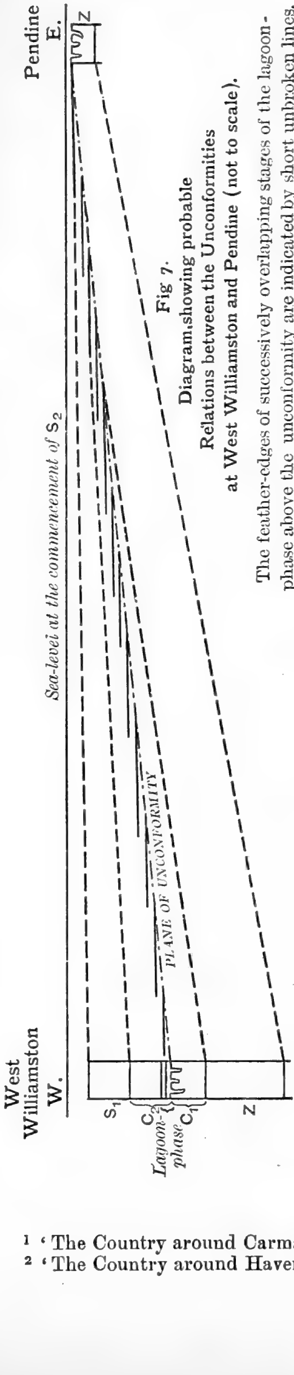


Fig 7.
Diagram, showing probable Relations between the Unconformities at West Williamston and Pendine (not to scale).

The feather-edges of successively overlapping stages of the lagoon-phase above the unconformity are indicated by short unbroken lines.

(Carmarthenshire),[1] on the other (the northern) side of the coal-basin, the whole of C_2+S_1 has been overlapped by S_2.

Though the above statement suffices for the purpose of this section, it is advisable here to consider a little further the interrelations of the developments at West Williamston and at Pendine. At the latter place limestones, apparently no younger than Z, are followed in order by (1) a limestone-conglomerate; (2) a few feet of lagoon-deposits—barren, black calcite-mudstones; and (3) good representatives of S_2 and D, commencing with the base of S_2. There is evidence, in the composition of the conglomerate and in 'contemporaneous piping' of the limestones below, that the latter are separated from the conglomerate by a true unconformity: that is, that they were raised above sea-level and eroded subaërially prior to the deposition of the conglomerate. Here the unconformity is marked also by a considerable hiatus in the sequence; on the other hand, at West Williamston, the only place on the south side of the coal-basin where an unconformity in the sequence is evidenced, the break is slight and lies between C_1 and C_2, in other words, on a horizon in the middle of the hiatus at Pendine. Nevertheless, a consideration[2] of the general development of the Avonian in the South-Western Province leads to the conclusion that the unconformities at both places have been caused by one series of earth-movements. The magnitude of the hiatus at Pendine, and the fact that the horizon of the uplift in evidence at West Williamston lies within this hiatus, are explicable

---

[1] 'The Country around Carmarthen' Mem. Geol. Surv. 1909, pp. 81–82.

[2] 'The Country around Haverfordwest,' Mem. Geol. Surv. (in the press).

on the supposition that beds below the plane of unconformity are overstepped between the latter place and Pendine and that beds above that plane are overlapped in the same direction (see fig. 7, p. 527). Both of these phenomena are to be expected, though the extent of the overlap above the unconformity is surprising. Further, the presence of lagoon-deposits at the base of the overlapping series at Pendine and some other places along the same outcrop, as well as at West Williamston, suggests that across the unexposed ground between the latter place and Pendine the unconformity is succeeded, as a rule, by lagoon-deposits. This is also indicated diagrammatically in fig. 7.

The deeper-water limit of all horizons of the phase is reached in the south: for they are represented by ordinary limestones in the Mendips, South-Western Gower, and Southern Pembrokeshire.

The lagoon-phase at the top of S_2 has not been followed out in detail northwards; neither has its complete seaward limit been reached, although in Gower and Pembrokeshire it is poorly developed in the southernmost outcrops, its phasal deposits being there largely replaced by ordinary limestones.

(6) Earth-Movements accompanying Lagoon-Conditions.

The deposition of a lagoon-phase involves the fulfilment of certain conditions. Some of these are enumerated in paragraph 1 (below). Again, certain conclusions may be drawn from the development in the South-Western Province of the *Modiola* phases present in Gower: as the latter are few, these conclusions are provisional; but as, at the same time, the evidence is consistent, it may be useful to note its trend. It will also be seen that the deposition of the Gower radiolarian phase appears to have followed an earth-movement similar to one which preceded the deposition of the *Modiola* phase at the base of C_2.

1. The accumulation of extremely shallow-water deposits to any considerable thickness can have been conditioned only by a general depression of the sea-bottom relative to sea-level—positive movement—over the area of deposition. Further, the depression has been isostatic,—the term 'isostatic' being used simply in a descriptive sense, to denote the state of an area over which the rate of sedimentation is equal to the rate of depression. Lagoon-phases are, by definition, extremely shallow-water deposits; the accumulation of each has, therefore, been accompanied by isostatic depression, provided its thickness is greater than the range of depth of the water in which it has been deposited.

2. The internal constitution of the Gower *Modiola* phases (see Table III, 4, p. 514) suggests (i) that in some cases (Km and the top of S_2) isostasy has been interrupted; but that in the other (the base of C_2+S_1) it has been accurately maintained, practically throughout the duration of the phase.

3. A consideration of the nature of the beds below and above and

of their relations to the phases (see Table V, 1, p. 526, and 'Variations in Depth, etc.' pp. 532 *et seqq.*) leads to the further conclusions:—(ii) The periods of isostasy recorded in the phases have followed either a movement of elevation (in the case of the phase at the base of C_2+S_1); a continental period, during which depression has not been exactly counterbalanced by sedimentation (in the case of Km); or a shallowing, marine period (in the case of the phase at the top of S_2). (iii) Each period of isostasy has been ended by a sudden movement of depression.

4. Taking into account, also, the fact that the lagoon-areas have been coastal features, we may generalize the two last conclusions (par. 3) thus,—lagoon-areas have been developed during periods of steady depression, more or less prolonged, which have either marked the first stage of the submergence of a foundering coast, or followed intervals of upward movement interrupting a general downward movement of a sea-floor. (The one condition is probably a particular case of the other.) These periods of steady depression have preceded more rapid subsidences.

It follows, as a corollary, that lagoon-phases may be expected to accompany transgressions, as do Km and the phase at the base of C_2+S_1, but also that they will be subject to overlap by the deeper-water deposits that have succeeded them.

5. The phase at the base of C_2+S_1, of which our knowledge is most complete, persisted far longer in the northern than in the southern part of the Bristol area; for in the north it is succeeded by S_1 beds, whereas at Weston it is confined to the base of C_2. The significance of this fact lies in the greater proximity of the former region to the Avonian coast. In the western area (Pembrokeshire and Pendine) also, the phase apparently persisted longer near the Avonian land than elsewhere (fig. 7, p. 527), although there the matter is complicated by overlap of higher horizons over lower. It appears, therefore, that the depression that closed the phase affected the seaward margin of the lagoon-area before the more landward parts. The depression was greatest in the south, both in the Bristol area and in the west.

No such landward lag is known in the case of the depression that ended the lagoon-phase at the top of S_2.

The radiolarian phase.—The conclusions regarding earth-movements, detailed above, afford a means of testing the hypothesis that the radiolarian cherts at the base of P are similar in origin to the *Modiola* phases on which those conclusions are based.

The formation of the cherts was preceded in Gower by a shallow-marine period (D_1 to D_{2-3}). The following evidence suggests that this period was closed by elevation. At Ifton,[1] near Newport (Mon.), on the east, as well as at Haverfordwest[2] on the west, Millstone Grit, similar lithologically to the band that succeeds the

---

[1] Rep. Brit. Assoc. (Winnipeg) 1909, p. 478.

[2] O. T. Jones, 'Summary of Progress for 1906' Mem. Geol. Surv. 1907, p. 53.

radiolarian cherts in Carmarthenshire immediately and conformably, rests unconformably upon S_2; at Ifton cavities (channels and swallet-like passages) penetrating the limestone to a depth of at least 40 feet below its uneven upper surface have been filled with an original deposit of Millstone Grit. The undisturbed character of the Grit in the cavities shows that, here as at the Haverfordwest occurrence described by Prof. O. T. Jones, the limestone was raised above sea-level and 'piped' by subaërial erosion prior to the deposition of the Grit. No direct evidence as to the exact period of the elevation is available; but the fact that the change from D_{2-3} to P has been marked by a considerable physiographic change in the South-Western Province (p. 524) suggests that the movement took place at the close of D.[1] The relationship of the uplift to the hiatus between S_2 and the Millstone Grit would then be analogous to the relationship of the uplift at the end of C_1 to the hiatus between Z and S_2 at Pendine (fig. 7, p. 527). Outside the South-Western Province, evidence of emersion between D and P has been found in places by Dr. Sibly and Mr. C. B. Wedd, although, as a rule, there is no such break at this horizon.[2]

It appears, therefore, that the radiolarian cherts of the South-Western Province have been the first deposits formed after a movement of elevation which has left indubitable traces in that area. Consequently, tested in this way their suggested relationship to *Modiola* phases receives support.

(7) Lagoon-Phases outside the South-Western Province.

In conclusion, it may be mentioned that the conditions under which the lagoon-phases of Gower have been deposited have been paralleled elsewhere and at many other horizons. Where, in such cases, the sediments have a calcareous, or a calcareous and argillaceous, facies, as, for example, the Burdiehouse-Limestone Group of Scotland, the Upper Rhætic and Cotham-Marble Group,[3] and the Solenhofen Slate, their origination in shallow areas or even lagoons has been generally recognized, despite the fine grain of some of their most characteristic rocks. It is of interest, therefore, that several resemble the phases of Gower, not only in this fine grain and, frequently, in a fine lamination, but also in their relation to earth-movements.

As regards the radiolarian phase at the base of P, though it is not suggested that all radiolarian deposits have had a similar origin, it is certain that some, at least, of those which appear, from various considerations, to have been deposited in shallow water

---

[1] It is not, however, suggested that the movement resulted in unconfomity everywhere, for in Carmarthenshire the sequence both below and above the radiolarian cherts is unbroken; see T. C. Cantrill, 'The Country around Ammanford' Mem. Geol. Surv. 1907, pp. 72–76.

[2] Q. J. G. S. vol. lxiv (1908) pp. 63 & 81.

[3] The Lower Rhætic appears to be less peculiar in its rock-types than the Upper.

possess features linking them so closely with the Gower cherts that they, also, may be inferred to have been formed under lagoon-conditions. As an example may be cited the Gondwana plant-beds with radiolaria, described by Dr. A. K. Coomáraswámy[1] as having been 'deposited in comparatively shallow water.' They resemble the Gower cherts in their fine grain and very thin bedding; and, like various lagoon-phases, they occur near the base of a transgressing series, for they lie a short distance above gneiss, from which they are separated by merely a small thickness of sandstone, etc.

The close connexion between the development of lagoon-areas and certain earth-movements, discussed in the preceding section, and their locus on coastal shelves are related, possibly, to the fact that some *Modiola* phases, such as the Burdiehouse-Limestone Group, have been accompanied by volcanic outbreaks, including the effusion of lavas which possess a pillowy structure,[2] though the available data are insufficient to show whether such outbreaks have been connected with *Modiola* phases to a greater extent than with the contemporaneous standard deposits.

In this connexion, however, it is important to note that radiolarian cherts in various parts of the world are frequently accompanied by volcanic rocks, especially lavas possessing a pillowy structure; and, as bearing on this aspect of the subject and the views which I have ventured to put forward, the following words of Prof. Charles Lapworth are significant. Speaking of a hypothetical area on which radiolarian cherts and associated igneous rocks might be supposed to have been deposited, he said[3]:—

> 'Consider, for example, such an area as originally forming part of a slightly submerged continental shelf, or coastal platform, with volcanic and archipelagic conditions, and overlooking . . . . . . a broad and deeper sea. Suppose, further, the platform itself floored by rocks already metamorphosed, and that this platform remains covered by shallow waters for an extended period of geological time, while the sea-floor in front of it is continually deepening. Under these conditions, only such mechanical, volcanic, or organic material could become accumulated as rock-layers on the submerged platform, as by their original nature or rapid cementation were incapable of being swept off by the waves and currents of the shallow waters into the open and deepening sea beyond. Such rock-formations as would be accumulated on the platform would necessarily be thin, but would be lithologically varied and peculiar.'

This graphic passage, with certain modifications, embodies the general conclusions to which I have come as to the situation in which lagoon-phases, so 'varied and peculiar' in their features, have been deposited. The chief difference lies in my interpretation of some of those features; they point to the dominance of comparatively still water within the shallow area.

---

[1] Geol. Mag. 1902, p. 305; see especially p. 306.

[2] Sir Archibald Geikie, 'Central & West Fife & Kinross' Mem. Geol. Surv. 1900, p. 54.

[3] Q. J. G. S. vol. lviii (1902) p. 440.

V. Interpretation of the Lithological Sequence [E. E. L. D.].

(1) Preliminary Remarks.

Apart from many minor variations in rock-type, a general sequence of facies (Table II, p. 505) is presented by the Avonian of Gower. In the following interpretation of this sequence it has been assumed that those true oolites—that is, rocks consisting chiefly of typical, concentric and radially-crystalline ooliths,—that are widespread have been deposited in shallow water. The assumption is justified by the current-bedding of such rocks and the frequency of fragments of contemporaneously-formed oolite in them, as well as by what is known both of the conditions determining the formation of ooliths[1] and of the situations in which ooliths are found at the present day. The oolites include some of the purest of the Avonian limestones, but the fact that limestones practically free from terrigenous material may be formed in shallow, coastal waters is so well known as to need no emphasis.

The differences between the three districts (see Table I, facing p. 505) will be discussed later.

(2) Variations in Depth and other Conditions of Deposition over Gower as a whole at Successive Times; Conclusions; Earth-Movements.

The variation of depth in time is represented diagrammatically by fig. 8 (p. 533). In this there is no true vertical scale; the depth-line indicates merely periods of extreme shallowness, and, by the direction of its slope, shallowing or deepening. For horizontal scale, the duration of a subdivision is arbitrarily and only approximately made proportional to its thickness.

In the following discussion, on which the figure is based, separate reference will not be made to the depth of the *Modiola* phases; in accordance with the views already put forward, they are represented as extremely shallow, but with some interruption in the case of Km and, to a greater extent, in that of the top of S_2 (see Table III, 4, p. 514).

(i) The change from Upper Old Red Sandstone to Km.—This was a change from 'continental' to marine conditions: it is represented in fig. 8 (p. 533) by the depth-line passing below sea-level. The change was sudden, and was unaccompanied, so far as known, by marine intercalations in the top of the Old Red or continental recurrences in the base of Km; but, despite a little current-action, deposition was practically continuous.

(ii) The change from Km to K_1.—Sharp increase of depth.

(iii) Conditions during K.[2]—The sea was muddy, but sup-

---

[1] G. Linck, Neues Jahrb. Beilage-Band xvi (1903) p. 495; and L. W. Collet, 'Les Dépôts marins' Paris, 1908, pp. 282–83.

[2] On the supposition that K is equivalent to the Lower Limestone Shales (see p. 496).

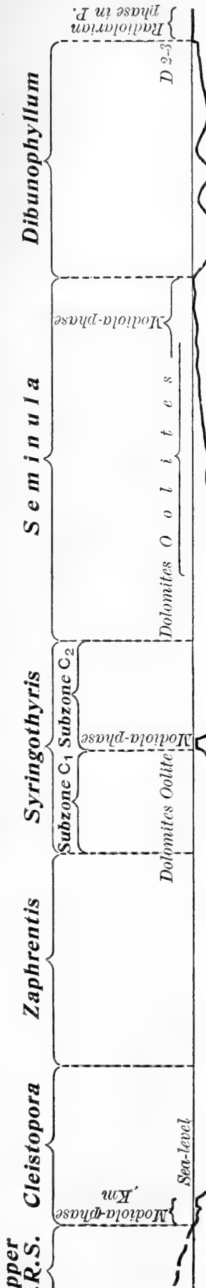


Fig. 8.—*Diagram showing the variation in depth of the Avonian Sea at successive times, deduced from the sequence in Gower.*[1]

ported a rich calcareous fauna belonging to standard groups, chiefly crinoids and brachiopods; the remains are found in both the shales and the subordinate limestones. In Gower, as in the South-Western Province generally, the conditions, for some reason, were unfavourable to the formation of chert and dolomite. The thick limestone in the middle of the zone, which is widespread, consists partly of oolite, and may, therefore, have resulted from a temporary shallowing (fig. 8).

(iv) The change from K to Z.—Probably in Gower, and certainly over the western part of the South-Western Province, this change of fauna was accompanied by a rapid and long-enduring lithological change, from a dominantly argillaceous to a dominantly calcareous facies of sedimentation: for there the junction of the zones is the junction of the Lower Limestone Shales with the main limestone-mass of the Carboniferous Limestone Series. This widespread change in fauna and rock-type probably resulted from some important physiographic event elsewhere, but apparently it was not accompanied in Gower by change of depth, for the Z limestones closely resemble the thin limestones in K. It is noteworthy that 'contemporaneous' dolomitization and the formation of chert practically came in at the period of the change; chert is especially frequent near, but not below, the junction.

(v) Conditions during the two sequences: (1) Z, C_1 and the *Modiola* phase at the base of C_2; and (2) C_2 & S.—A close parallel may be drawn between these two sequences, especially in South-Western Gower where the lithological series is

---

[1] For explanation, see V, § (2), pp. 532 *et seqq.* The bracket against the *Modiola* phase at the top of S_2 is unclosed on the left, as the phase commences indefinitely. In accordance with the conclusion on p. 521, the radiolarian phase at the base of P is represented as deposited in as shallow waters as those of the *Modiola* phases.

most varied and most typical of the South-Western Province generally. In the following table the members of each sequence are placed in order of superposition, and lettered like the parallel member of the other sequence:—

(1) The sequence Z, C_1 and the base of C_2:—	(2) The sequence C_2 and S:—
d. *Modiola* phase at the base of C_2.	*d.* *Modiola* phase at the top of S_2.
c. *Caninia* Oolite.	*c.* S_2 oolites.
b. *Laminosa* Dolomites (dolomitized crinoidal limestones); in Eastern & North-Western Gower with similar dolomites of Z-age.	*b.* Partly dolomitized gasteropod-limestones, most conspicuous in S_1.
a. Crinoidal limestones, some dolomitized; lower part or all of Z.	*a.* Various limestones, some dolomitized; C_2 with part of S_1.

The chief differences between the two sequences are (1) dolomitization has been much less complete in S_1 than in the *Laminosa* Dolomites; (2) the S_2 oolites, on the contrary, are much thicker and include dolomites more frequently than the *Caninia* Oolite; (3) the S_2 oolites pass gradually into the overlying *Modiola* phase, whereas the *Caninia* Oolite is separated from the parallel phase by a sharp line and, in places, contemporaneous erosion. (In fig. 8, p. 533, the passage of the S_2 oolites into the *Modiola* phase is indicated by the overlapping of unclosed brackets.)

As regards interpretation, it is clear that in each sequence the establishment of the *Modiola* phase (*d*), that is, of lagoon-conditions, has been preceded by a considerable period during which shallowness of the sea, though less extreme than during the phase itself, has had a marked effect on the facies of sedimentation: this is shown by the presence of thick dolomites (*b*)[1] and oolites (*c*) below each phase. But it is uncertain what cause has led to the replacement, in each sequence, of dolomite- by oolite-formation, for the two sequences are sufficiently parallel to suggest that the cause has been similar in both. Though, in view of the frequency of contemporaneously-eroded fragments in the oolites (*c*), we may well suppose that the waters in which these rocks have been formed have been shallower than during the preceding dolomitic stages (*b*)—just as the latter have been shallower than the preceding stages (*a*),—it seems probable that oolite-formation has depended on some condition additional to shallowness. For, in the Avon, the incoming of S_2 is marked, as at many places in the South-Western Province, by the

---

[1] The view of Prof. E. W. Skeats, Q. J. G. S. vol. lxi (1905) pp. 133–38, and others, that within certain limits shallowness favours dolomitization, is adopted; it is supported by the relations observed (see below, p. 537) between dolomitization and the probable relative depths of the Avonian sea. Although S_1 thus bears evidence of deposition in shallower waters than those of C_2 in Gower, in the Avon it includes some limestones of deeper-water origin than any in C_2.

appearance, for the first time in S, of thick oolites; but, at the same time, S_1 appears, from the recurrence through it of lagoon-deposits, to have been deposited in waters even shallower at times than those of the S_2 oolites.

It may be noticed that, throughout the series Z–S in Gower, the junctions of the zones and subzones do not correspond with marked lithological changes, except in the cases of C_1 with C_2 and (possibly in places) of S_1 with S_2.[1]

(vi) The change from the *Modiola* phase at the top of S_2 to D_1.—The rapid replacement of the *Modiola* phase by deposits of open-sea, though shallow-water, facies points to rapid but not great deepening; the ensuing deposits yield a D fauna, and constitute the basal beds of the D zone. The migration of the D fauna from the region where it had developed into our area appears to have coincided, therefore, with a deepening. The increase of depth was probably immaterial, however, for the preceding fauna was ousted both over areas where standard conditions had been dominant during S_2, even to the end, as in South-Western Gower, and over those where lagoon-conditions prevailed towards the close of that time, as in Eastern and North-Western Gower.

(vii) Conditions during D_1 and D_2 or D_{1-2}.—No rock-sequence comparable with that above the *Modiola* phase at the base of C_2 exists in D. The initial deepening of the area of deposition appears to have been slight and brief: for, once or twice during D_1 thin coals and underclay have been deposited, pointing to but little depth at those times, though not necessarily to actual terrestrial conditions. These shallow periods are indicated by the peaks in the depth-curve in fig. 8 (p. 533). It is noticeable that, despite the shallowness, a lagoon-phase has not been established, the coal being intercalated among standard marine limestones.

(viii) The change from D_2 or D_{1-2} to D_{2-3} (Upper Limestone Shales).—The incoming of the D_{2-3} fauna accompanied a reappearance of shale-depositing waters: such waters had been practically absent from our area since K-times. The D_{2-3} deposits, however, were much more calcareous than those of K; and both chert and dolomite were formed in considerable amount.

(ix) The change from D_{2-3} to the radiolarian phase at the base of P.—In regard to depth of deposition, this change resulted from the substitution of comparatively shallow conditions by what appear to have been lagoon-conditions (p. 521). In regard to facies of deposition, it resulted from a replacement of the calcareous (or calcareo-argillaceous) conditions that had prevailed in Carboniferous times hitherto by the non-calcareous conditions—whether cherty, argillaceous or arenaceous, marine or non-marine—that prevailed in the South-Western Province for the rest of Carboniferous times.

(x) Conditions during P.—Little is known with certainty

---

[1] In South-Western Gower, where the series has been most closely examined, the S_2 oolites come in a short distance above the base of S_2.

of the poorly-exposed sequence above the radiolarian cherts; the P-shales, which form the lower part of the Millstone Grit Shales of the Geological Survey, pass up insensibly through the higher part into the Coal Measures— the latter being, in part at least, a 'continental' deposit.

Conclusions.

(1) The time represented by the Gower succession discussed above may be divided into four periods, namely (i) Km–C_1; (ii) C_2 – S-oolites; (iii) top of S_2 – D_{2-3}; and (iv) P. During these periods the depth varied as follows:—

(i) Km–C_1. The area at first was under lagoon-conditions (Km); its depth increased sharply (K & Z), and later diminished, in all probability progressively but intermittently (Z to *Laminosa* Dolomites; *Laminosa* Dolomites to *Caninia* Oolite), ultimately attaining that of lagoon-conditions again by the time that the next period was initiated.[1]

(ii) C_2 – S_2 oolites. The area, with the exception of the South-Western district, at first was under lagoon-conditions (*Modiola* phase); its depth increased abruptly—to an amount during the rest of C_2 greater, probably, than at any other Avonian horizon, and later diminished, again, it would appear, progressively but intermittently (S_1; S_2), to that of lagoon-conditions by the time that the next period was initiated. The stage of oolite-formation was greatly prolonged, and the shallowness which marked it culminated in the lagoon-conditions that followed.

(iii) Top of S_2–D_{2-3}. The area at first was under lagoon-conditions (*Modiola* phase); its depth increased rapidly, though probably to no great amount, and later was at times very slight[2] (coal and underclay in D_1).

(iv) P. The area at first appears to have been under lagoon-conditions (radiolarian phase), but its subsequent history during P is uncertain. The ultimate replacement of marine waters by continental ones (Coal Measures) was probably gradual.

(2) The foregoing summary of the periods shows that during each of the first three the area has undergone a bathymetrical cycle, complete in the case of the first two and probably in that of the third also; in each of the three cases initial shallowness, that of lagoon-conditions, has been followed by rapid deepening and, later, by shallowing, which, unlike the deepening, has been prolonged. The shallowing has, however, been more regular in the first two than in the third period.

Earth-Movements.

(3) Both the deepening and the shallowing have probably resulted

---

[1] At some places in the South-Western Province, such as West Williamston, the shallowing culminated in emersion, the lagoon-conditions being established as the land again sank at the commencement of the next period.

[2] At some places in the South-Western Province (see pp. 529-30) this period probably ended in emersion.

from earth-movements. The shallowing may be due to accumulation of material, but, for several reasons, has more probably resulted from movements of elevation (negative movements). Thus, in two of the cycles it appears to have been progressive and intermittent; and in one (if not two) it has been completed in parts of the South-Western Province by emersion.

(4) If we knew the exact depth in feet at which each uniform group of the series had been deposited and the time occupied in the deposition, by adding, for each group in turn, depth to total thickness of deposit already formed, we could construct a curve with these totals as negative ordinates and total times as abscissæ. This curve would show the movement of the base of the Carboniferous throughout Avonian time. It would then be seen that the negative movements above mentioned have been mere incidents in a prolonged spell of depression (positive movement). Thus, although the incoming of oolites in S_2 has, doubtless, been accompanied by a certain amount of negative movement, their deposition to the thickness which they attain can have been conditioned only by a renewal, and for a long time, of depression. In this case, where the thickness of the deposit is enormous relatively to any possible range of depth during its formation, depression has been approximately isostatic (in the sense in which that term is used on p. 528).

(3) Relations between the Different Districts of Gower at Successive Times; Conclusions; Earth-Movements.

The following interpretation is placed on the differences and resemblances between the three districts, summarized in Table I (facing p. 505).

(i) Of K little is known, but during the deposition of Horizon β the facies of sedimentation was practically uniform over the whole area.

(ii) During the interval, Z and the lower half of the *Laminosa* Dolomites, dolomitization was much more extensive in Eastern and North-Western Gower than in South-Western Gower; this difference accords with the view of Prof. Skeats[1] and others that within certain limits shallowness favours dolomitization, for the Avonian sea is known from other evidence to have shallowed northwards in the South-Western Province.

(iii) The facies of sedimentation of the rest of C_1 was practically uniform over the whole area, though the ratio of the two rock-types formed, dolomite and oolite, varied.

(iv) The fact that lagoon-conditions were established at the base of C_2 in Eastern and North-Western Gower but not in South-Western Gower was doubtless due to the southward deepening of the Avonian sea. At this period, however, part of the Eastern

---

[1] Q. J. G. S. vol. lxi (1905) pp. 133–38.

District approximated to the conditions of South-Western Gower: for at Longland Bay the base of C_2 is not a *Modiola* phase, but a group of dolomites representing standard gasteropod- and other limestones.

(v) In the character of C_2 and S_1 Eastern Gower definitely links itself with South-Western Gower, and dissociates itself from North-Western Gower. In one respect, namely in an absence of 'contemporaneous' dolomite and chert from the last-named district, this difference, between Eastern and South-Western Gower on the one hand and North-Western Gower on the other, persists to the top of D. The difference is marked in the case of dolomitization, because outside North-Western Gower many horizons have been affected by this alteration. As a similar difference between southern and northern outcrops is almost as noticeable in South Pembrokeshire; and as, further, outcrops to the north of either Gower or South Pembrokeshire are largely if not entirely devoid of 'contemporaneous' dolomitization at horizons above C_1, it is evident that a widespread influence inhibiting such dolomitization—to which alteration the conditions of deposition at many horizons would have been favourable—existed in the coastal waters of the Upper Avonian sea. In Gower this influence first made itself felt in C_2; its nature, however, is unknown.

(vi) During the interval, S_2 and D_1, the facies of sedimentation in different parts of the area varied little except in dolomitization, as mentioned above; at the top of S_2, lagoon-conditions were but occasionally established in South-Western Gower.

(vii) Though the greater part of the 'black lias,' D_{2-3}, of the Eastern District doubtless corresponds to the same group of the South-Western, some of it, Dr. Vaughan concludes (p. 552, table), has been deposited during the formation of part of the comparatively pure D_2 limestones which underlie D_{2-3} in the latter district. That is, argillaceous limestones and shales in Eastern Gower are the contemporaries of pure limestones in South-Western Gower. D_2 is present in North-Western Gower also, and reappears in force, as a mass of pure limestones, along the North Crop of the coalfield at Mynydd-y-gareg near Kidwelly,[1] 12 miles farther north still. The occurrence of the pure limestone facies so far north would point to the existence of a marked embayment in the Avonian coast hereabouts, on the supposition that D_{2-3} was deposited in waters essentially shallower than those of D_2 in its 'pure' development.[2] It is more probable that the difference between D_{2-3} and D_2 is primarily independent of depth. For, north-east of Mynydd-y-gareg, along the North Crop between that place and Garn-bwll (Carmarthenshire), the pure limestone facies of D_2 gives place laterally to dark sandy limestones with chert,[3] that is, to

---

[1] 'The Country around Carmarthen' Mem. Geol. Surv. 1909, p. 79.

[2] This is the view of Dr. Vaughan, Rep. Brit. Assoc. (Winnipeg) 1909, p. 190.

[3] T. C. Cantrill, 'The Country around Carmarthen' Mem. Geol. Surv. 1909, pp. 76–77. He tells me that this facies continues for a great distance east of Garn-bwll.

beds that differ lithologically from the 'black lias' at the same horizon in being sandy instead of argillaceous. This lateral passage is observable practically due north of the change from pure limestone to 'black lias' in Gower. In other words, sand was being deposited in the north contemporaneously with mud at a considerable distance to the south; while at a short distance to the west of both places the water was clear. Such conditions are most readily explained on the supposition that the region lay at the western margin of the sediment brought into the Avonian sea by a southward-flowing river.

(viii) The deposition of 'black lias' in South-Western Gower above D_2, while it persisted in the Eastern District, points to an extension of the muddy waters described in the preceding paragraph.

(ix) This widespread and progressive incoming of argillaceous rocks and sponge-cherts towards the end of D probably foreshadowed the marked advent of shales and cherts, spicular or radiolarian, at the commencement of P. The P-shales, therefore, may, also, have derived much of their material in the area here described from a southward-flowing river. With this view their general character and the lateral passage[1] northwards of some part of them, or of the overlying shales, into the comparatively-coarse basal Millstone Grit of the North Crop are in full agreement.

Conclusions.

(1) In the facies of Z and the lower half of the *Laminosa* Dolomites the Eastern District resembles the North-Western, and both differ from South-Western Gower; but in that of the rest of C_1 there is no marked difference between the districts: while, in the development shown by C_2, S, and D_1, the Eastern District links itself with the South-Western and both differ from North-Western Gower.

(2) These resemblances and differences are probably attributable to the fact that the depth of the Avonian sea and the influence of the Avonian coast differed in the several districts; for similar differences are observable in Pembrokeshire also, in different outcrops bearing the same relations to the probable position of the Avonian coast as do the parallel districts of Gower.

(3) The evidence afforded by the thicknesses of the zones and subzones in the different districts (Table I, facing p. 505) leads to the same grouping as the evidence summarized in (1). Thus:—

Zone Z and the *Laminosa* Dolomites together are at least 50 per cent. thicker in the South-Western than in the Eastern and North-Western Districts;

The *Caninia* Oolite and C_2, though variable, show no marked increase in any direction;

Zone S is 50 per cent. thicker in the South-Western and Eastern than in the North-Western District; and

Zone D is thicker, probably in even greater ratio, in the South-Western and Eastern than in the North-Western District.

---

[1] A. Strahan, Swansea Memoir, p. 29.

In passing, it may be remarked that the sequence, Z–D inclusive, is thicker collectively in South-Western Gower than at any other place in the South-Western Province where it has been measured; and that D is more completely developed in this district, also, than anywhere else in the same province.

Earth-Movements.

(4) The thicknesses, when combined with the depths at which the deposits have been formed, in the manner outlined on p. 537, paragraph (4), would enable us to compare the magnitudes in the different districts of each earth-movement that accompanied deposition. In our general ignorance of exact depths, this can be done only for the summations of the various movements between those horizons that appear to have been deposited at a uniform depth in all districts. Of such horizons the most useful are the lagoon-phases, on account of their well-defined character and the certainty that differences between different districts (as regards average depth of deposition of any phase) are negligible, the range of depth in a lagoon-area being small. To apply the method:—

The first datum-horizon is Km, which is probably developed throughout Gower. By the time that the next datum-horizon, the base of C_2,[1] was initiated, Km had been buried more deeply in the South-Western District than in North-Western or Eastern Gower, by an amount equal to the difference between the thickness of the deposits formed in the interval in the first district and that formed in the others; this difference, on the justifiable assumption that K was no thicker in the North-Western and Eastern districts than in the South-Western, was at least 300 feet (see Table I, facing p. 505). In the interval between Km and the base of C_2, therefore, depression was greater, by at least 300 feet, in South-Western than in North-Western or Eastern Gower.

In the same way, by the time that the next datum-horizon, the top of S_2, was reached, the base of C_2 had been buried at least 400 feet deeper in the South-Western (see, however, previous footnote) and Eastern Districts than in North-Western Gower. And, if the radiolarian cherts at the base of P are a lagoon-phase and may, therefore, be regarded as a datum-horizon, by the time that their deposition was commenced the top of S_2 had been still more deeply buried in South-Western and Eastern than in North-Western Gower.

(5) From the preceding conclusions it is seen that the earth-movements that accompanied deposition were differential and that the regions of deeper water were the more depressed.

On the assumption[2] that the differential movements were widespread tilts, not irregular faulting or folding, the axis about which

---

[1] In South-Western Gower the base of C_2 is not a lagoon-phase, but the fact that it is there represented by deeper-water deposits only emphasizes the conclusion that follows.

[2] That assumption is justified, in the case of the Upper Avonian movements, by the fact that throughout those movements the Eastern and South-Western Districts were depressed *pari passu*.

hinged the total movement during the first interval, Km–C_1, that is, the Lower Avonian (see § VI) movement, was approximately parallel to the line connecting the Eastern and North-Western facies. (This line is given with sufficient accuracy by the line of outcrop between the Eastern and the North-Western Districts). Similarly the axis during the two succeeding intervals, C_2–top of S_2, and D_1–D_{2-3} (that is, the axis of the Upper Avonian movements), was approximately parallel to the line connecting the Eastern and South-Western facies. Although this line was subsequently distorted beyond determination by pre-Triassic movements, it was evidently not parallel with the former axis. The axis of the Upper Avonian movements differed in direction from that of the Lower Avonian movement.

Summary of §§ III, IV, & V.

III. Pseudobreccias resemble true breccias outwardly, but their structure has resulted from patchy recrystallization of calcite in foraminiferal calcareous 'mud.'

IV. Lagoon-phases are rock-groups which have been deposited in extremely-shallow, coastal waters; they are characterized by an exceedingly-fine grain and peculiar faunas.

The radiolarian cherts of Gower and of the Culm of the West of England are concluded to be lagoon-deposits.

Lagoon-phases have marked the commencement of cycles of earth-movement.

V. Three bathymetrical cycles can be traced in the formation of the Carboniferous Limestone Series (Zones K–D) of Gower.

These cycles resulted largely from earth-movements, in which depression, on the whole, by far exceeded uplift.

Depression was greater in the seaward than in the landward regions; and the direction of the hinge of the Lower Avonian movement differed from that of the Upper Avonian movements.

It is a pleasure to recall the assistance which I have received in various ways from my colleagues on the Geological Survey and from other geologists. To Dr. J. J. H. Teall I am indebted for permission to publish some observations made in the course of my official work in Pembrokeshire. Dr. A. Strahan I have to thank for placing at my disposal the information obtained during the geological survey of Gower. Reference has been made on previous pages to Mr. T. C. Cantrill, who worked with me for a time on the ground and has put his detailed knowledge of the Carboniferous of adjacent areas at my disposal; Prof. L. Cayeux; Mr. H. Dewey; Mr. T. C. Hall; Mr. J. G. Hamling; Mr. J. A. Howe; Dr. W. Pollard; and Dr. R. L. Sherlock. To all these workers my heartiest thanks are due.

VI. NOTES ON THE DELIMITATION OF THE UPPER FROM THE LOWER AVONIAN IN THE SOUTH-WESTERN PROVINCE.

(1) Stratigraphical Considerations [E. E. L. D.].

The earth-movements discussed in the previous section (pp. 536–37), and the faunal, lithological and stratigraphical changes which are connected with them, afford a basis for a delimitation of the divisions of the Avonian in the South-Western Province. In applying this principle, it is advisable to include a lagoon-phase in the base of a division rather than to associate it with the underlying rocks, because such phases, in general, mark the commencement of cycles of earth-movement.

For these reasons the base of the *Modiola* phase at the base of (C_2+S_1), that is, the divisional line between C_1 and C_2, is the appropriate horizon at which to separate, as is necessary, an Upper from a Lower Avonian.[1] It is the more suitable because it is sharply defined lithologically and, in places, is emphasized by unconformity with the underlying rocks. And this unconformity, there is reason to believe, is the commencement of the transgression that has brought the Upper Avonian to rest upon far older rocks in the northern part of the South Wales area.

In those places, however, which represent the deeper parts of the Avonian sea, not only does the unconformity disappear, but also, as the distance from the Avonian coast increases, the *Modiola* phase itself is lost, and ultimately the base of C_2 may become untraceable by lithological means. Faunal methods, however, are available, such as is afforded by the incoming of *Cyathophyllum* ϕ Vaughan, though, as will be seen from the following note by Dr. Vaughan, the extreme base of C_2 does not everywhere correspond to the maximum of the change of fauna in passing from the Lower to the Upper Avonian.

(2) The Faunal Relations of C_2 to the Beds below and above [A. V.].

Wherever, as at Burrington, etc., C_1 is composed of limestones of standard type, the C_1 fauna is a continuation of the γ facies, that is, an extension and amplification of the Lower Avonian fauna, and, locally, this fauna is persistent into the base of C_2 (as here defined on lithological grounds).

On the other hand, the main C_2 fauna exhibits the earliest establishment of genera and gentes which are especially characteristic of Upper Avonian time. For example:—

Corals:—

The gens of *Cyathophyllum* aff. *murchisoni*.
The genera *Campophyllum*, *Diphyphyllum*, and *Clisiophyllum*.

---

[1] The terms Upper and Lower Avonian are used provisionally, pending a general discussion of the Avonian of this and other areas, in some of which other terms, such as Viséan and Tournaisian, are already in use.

Brachiopods:—

The following gentes and groups:—

Productus corrugato-hemisphæricus.
Productus punctatus.
Productus elegans.
Productus pustulosus.
Productus sublævis.
Spirifer aff. *bisulcatus.*

The genera *Actinoconchus, Seminula, Dielasma.*

Furthermore, the C_2 and S_1 faunas are linked by

Cyathophyllum ϕ.
Cyathophylloid *Caniniæ.*
Early *Carcinophylla.*
Megastomatoid *Micheliniæ.*
Productus corrugatus, mut. C. (nearly equivalent to *Productus* θ of S_1).
Chonetes cf. *comoides* (of great size).
Certain large species of *Bellerophon* and *Euomphalus.*

(In fact, beyond the occurrence of *Lithostrotion* there is frequently no other distinction between C_2 and S_1.)

Dr. Gosselet in 'L'Ardenne' 1888, chap. xxii, includes the C_2 fauna (the *Productus-sublævis* Beds) with the typical S fauna above in a single 'assise,' the 'Calcaire des Ardennes.' The transition from the *Productus-sublævis* fauna into the basal *Pr.-corrugatus* fauna is, in fact, exactly that which marks the passage of C_2 into S_1 in the South-Western Province generally.

Hence it will be entirely in accordance with the faunal evidence to draw the line of division between the Upper and the Lower Avonian at the bottom of the main part of C_2. The divide will therefore lie within C_2, as at present defined, above the lowest part of the standard limestones, which contains a recurrent C_1 fauna.

VII. Faunal Lists [A. V.].

Note.—Here and in the Palæontological Section, repetition of full references is avoided by the following abbreviations:—

'Bristol Paper' = Q. J. G. S. vol. lxi (1905) pp. 181–305 & pls. xxii–xxix—'Palæontological Sequence in the Carboniferous Limestone of the Bristol Area,' by A. Vaughan.

'Rush Paper' = Q. J. G. S. vol. lxii (1906) pp. 275–322 & pls. xxix–xxx—'Carboniferous Rocks at Rush (County Dublin),' by C. A. Matley & A. Vaughan.

'Loughshinny Paper' = Q. J. G. S. vol. lxiv (1908) pp. 413–72 & pls. xlix–l—'Carboniferous Rocks at Loughshinny (County Dublin),' by C. A. Matley & A. Vaughan.

'Davidson' = 'Monogr. Brit. Foss. Brach.' vol. ii (1858–63), Palæont. Soc.

Except in the case of D_{2-3}, as explained below, no attempt was made to draw up an exhaustive list at any level; immediately the zonal position had been placed beyond doubt, further search was abandoned.

LOWER AVONIAN.

CLEISTOPORA ZONE (K).

South-Western District:

Km:

Only the base of K is exposed near Rhossili.

Brachiopods:—

Chonetes cf. *crassistria* Vaughan [1] (non M'Coy).
Eumetria aff. *carbonaria* (Dav.) Vaughan.[2]
Camarotœchia cf. *mitcheldeanensis* Vaughan.

Lamellibranchs:—

Modioliform species, including *Modiola* cf. *lata*.

Gasteropods:—

A small species of *Bellerophon* is common.

Ostracods.

ZAPHRENTIS ZONE (Z).

Z_1:

Eastern District: Threecliff Bay (indicated by the numeral 4).

South-Western District: Rhossili to Worm's Head (indicated by 1).

Corals:—

Small simple *Zaphrentis*—1 and 4 (rare).

Brachiopods:—

Productus burlingtonensis Hall, Vaughan—1 and 4.
Small *Chonetes*: [*Ch.* cf. *crassistria* predominating]—1 and 4.
Leptæna—4.
Orthotetid—1 and 4.
Spirifer aff. *clathratus* M'Coy, Vaughan—1 and 4 (abundant)
A small *Syringothyris* (cf. *S. typa* Winchell)—4.
Reticularia cf. *lineata* [3] (Martin) (Dav.)—1 (rare).
Athyris (Cliothyris) cf. *glabristria* (Phill.) (Vaughan)—4 (rare).
Camarotœchia mitcheldeanensis Vaughan—1.

Crinoids:—

Dichocrinus sp.—4. (Determined by Dr. F. A. Bather, F.R.S.)

---

[1] 'Bristol Paper,' pl. xxvi, fig. 2; also Q. J. G. S. vol. lxiii (1907) p. 458.

[2] 'Bristol Paper,' p. 302.

[3] This species differs very considerably from Martin's figure in the irregular and undulatory concentric wrinkles and in the prominence of the thick underlayer of close-set tubes from which the fringed bands composing the outer layer are formed.

Z_2 :

South-Western District: Rhossili to Worm's Head (indicated by 1).

(This subzone is also exposed at Threecliff Bay in the Eastern District; the beds are, however, here dolomitized, and fossils are indeterminable.)

Corals:—

Zaphrentis omaliusi[1] Ed. & H., Carruthers.
Zaphrentis konincki[2] Ed. & H., Carruthers.
Caninia cornucopiæ Mich., Carruthers.
All three are common in 1.

Brachiopods:—

The usual Z_2 assemblage: no list was drawn up.

Horizon γ.

South-Western District: Rhossili to Worm's Head (denoted by 1).

Corals: same as under Z_2, together with:—

Michelinia tenuisepta Ed. & H. and de Kon., *non* (Phill.).
Caninia cylindrica (Scouler in M'Coy) Vaughan.[3]

Brachiopods:—

Productus cf. *pustulosus*[4] Phill. (and cf. *Pr. christiani* de Kon.).
Semireticulate *Productus*.
Leptæna.
Orthotetid.
Spirifer aff. *clathratus* M'Coy, Vaughan.
Spirifer cinctus de Kon.[5]
Syringothyris cuspidata (Martin).
Syringothyris cf. *laminosa* (M'Coy) (Dav. *pars*), Vaughan.[6]

---

[1] = *Z.* aff. *phillipsi* Ed. & H., Vaughan: as described in 'Bristol Paper,' p. 270.

[2] = *Z.* aff. *cornucopiæ* (Mich.) Ed. & H.: as identified in 'Bristol Paper.'

[3] *Caninia cylindrica*, as employed in the 'Bristol Paper,' covered all the Caninias from the entrance of the genus at the top of Z_2 to the maximum of '*C. cylindrica*, mut. S_1,' in the Lower *Seminula* Zone. These would now be differentiated into *C. cornucopiæ*, *C. patula*, and *C. cylindrica* with variants of each; at the time of our work in Gower (in 1905), however, all these forms were lumped under *C. cylindrica*.

[4] A common form at several points of the South-Western Province and first appearing in γ: maximum at the top of C_1 and in C_2. The umbonal region is strongly wrinkled and pustulose, but the skirt is often almost smooth (cf. *Productus christiani*, which is abundant in C_2 of Belgium).

[5] *Spirifer cinctus* Fischer is an Upper D form and a near ally of *Sp. planicosta* (M'Coy): the form cited above is referred to as *Spirifer konincki* Dewalque by Belgian writers, and is an important zonal index of Z–C.

[6] The form here indicated accords with *Syringothyris* in its general build and area, but is more closely allied to *Spiriferina* in its umbonal plates. All Carboniferous Spiriferinas have a primitive syrinx which, however, remains undeveloped and is buried in, and filled in by, the umbonal callus. In the species here recorded, the syrinx is quite obvious, although confined to the apical portion of the delthyrium.

Syringothyris Zone (C).

Eastern District: Threecliff Bay (4) and Longland Bay (6).
South-Western District:—Cliff west of Overton.

C_1:

Composed of the *laminosa* dolomite and *Caninia*-Oolite.

Fossils are very scarce; narrow-tubed *Syringopora*, large-celled *Michelinia*, small *Zaphrentis*, large *Caninia*, and an early Clisiophyllid were, however, recorded from various places in Eastern and South-Western Gower, as well as a band of *Chonetes* cf. *comoides* and of *Bellerophon* in the *Caninia* Oolite of Longland Bay.

C_2:

Lowest part of the standard limestones.

Zaphrentis omaliusi Ed. & H., Carruthers—4 and 6.
Zaphrentis konincki Ed. & H., Carruthers—4 and 6.
Caninia cylindrica (Scouler in M'Coy) Vaughan—abundant in 4.
Syringothyris cuspidata (Martin)—4 and 6.
Syringothyris cf. *laminosa* Vaughan—rare in 4 and 6.
Cyathophyllum ϕ Vaughan (small mut.[1])—4 and 6.

UPPER AVONIAN.[2]

C_2:

Main part of the standard limestones.

Corals:—

Syringopora cf. *geniculata* Phill., Nicholson—4 and 6.
Syringopora cf. *reticulata*—4.
Michelinia grandis[3] M'Coy—4 and 6.
Zaphrentis konincki, mut. C_2[4]—6 (nearly at the top).
Caninia cylindrica (Scouler in M'Coy) Vaughan—4 and 6.
Cyathophyllum ϕ Vaughan—abundant in 4 and 6.
Diphyphylloid *Lithostrotion*—Overton.

Brachiopods:—

Chonetes cf. *comoides* (Sow.).
Rhipidomella aff. *michelini*—6.
Spirifer cf. *trigonalis*[5]—6.
Syringothyris cuspidata—4 and 6.
Seminula sp.[6] [cf. *S. ambigua* (Sow.)]—6.

---

[1] *Cyathophyllum* ϕ is not established until C_2; the small mutation is, therefore, a descending mutation, that is, a previously established member of the gens. It obeys the general law—'earlier and smaller.'

[2] The reasons for starting the Upper Avonian at this level are set out in § VI.

[3] = *Michelinia* cf. *megastoma* of my earlier lists.

[4] *Zaphrentis konincki* is a Z_2 to γ index; this mutation is, therefore, an ascending mutation: that is, a subsequently-established member of the gens. It is larger, and has longer intermediates, in accordance with the general rule. [See my note in R. G. Carruthers's paper, Geol. Mag. dec. 5, vol. v (1908) p. 70.]

[5] Small, sharply-ribbed form with a strong angular fold, somewhat produced.

[6] Deeply sinuate form, recorded as *Seminula ambigua* by Dr. T. F. Sibly, from Weston and the Mendips.

[5] & [6] These forms characterize the C–S level at widely separate localities in England; they are, therefore, important diagnostic forms.

Gasteropods:—

Large species of *Bellerophon* and *Euomphalus* are abundant.

Cephalopods:—

A large species of an Orthocerate is common.

SEMINULA ZONE (S).

S_1:

Eastern District: Threecliff Bay (4) and the cliff-section from Longland to Mumbles.

South-Western District: Overton (denoted by 2).

Corals:—

Michelinia grandis (M'Coy)—2.
Caninia (Cyathophylloid) *bristolensis*[1] Vaughan—2, 4 and 6.
Cyathophyllum ϕ Vaughan—2 and 6.
Lithostrotion cf. *irregulare* (Phill.) Ed. & H.—4, 6 (only at the base).[2]
Lithostrotion martini Ed. & H., and variants—2, 4, 6.
Diphyphyllid[3]—6 (only at the base).
Heterophyllia[4] sp.—2.

Brachiopods:—

Productus aff. *semireticulatus*, mut. S_1 Vaughan—2, with fragments of a large *Productus*.
Productus cf. *elegans* M'Coy—2 (abundant).
Chonetes cf. *comoides* (Sow.)—(persists at Overton as long as *Caninia*).
Seminula ficoides Vaughan, and varieties—2, 6 (very abundant).

Gasteropods:—

Bellerophon, *Euomphalus*, and *Loxonema* abundant—2, 6.

Bryozoa:—

Fenestellids and *Heterotrypa* cf. *tumida* (Phill.) crowd the shaly partings at Overton (2).

Trilobites:—A Phillipsid is common—2.

[The resemblance of S_1 at Overton to S_1 of the Avon is very striking, for the shaly partings are crowded with the same species of bryozoa enmeshed in a network of spines broken from the index *Productus* and accompanied by the same small trilobite; while the limestones themselves contain at both places *Caninia bristolensis* in abundance.]

S_1 of Gower only differs from S_1 of Bristol in that, in Gower, *Cyathophyllum* ϕ persists into S_1 and *Seminula* is established later.

---

[1] Proc. Bristol Nat. Soc. ser. 3, vol. x (1903) p. 103 & pl. i, fig. 4; = *Caninia cylindrica*, mut. S_1 of 'Bristol Paper.'

[2] This species differs from *L. irregulare* of the D levels in its strikingly ramulose habit. The beds in which it occurs have a typical C–S fauna, and were formerly considered by me to mark the top of C_2; it is somewhat more convenient to consider them as the base of S_1. In any case, C_2 and S_1 are faunally continuous both in (2) and (6).

[3] Diphyphylloid Lithostrotions are not uncommon in C–S, and again are very common in Upper D, but are apparently absent from S proper, where *Lithostrotion* reaches its maximum.

[4] Collected by the late Dr. W. B. Gubbin (Bristol Nat. Soc. *op. jam cit.*).

S_2 :

Eastern District: Longland to Mumbles section (6); Bishopston Valley (8).

South-Western District: Overton (2).

The Lower (cherty) part abounds in silicified clusters of a large *Lithostrotion*—*L. affine* (Flem.) Ed. & H. *Seminula* and *Productus* fill recurrent bands. Gasteropods are numerous.

The Upper (oolitic) part contains a fauna characteristic of the S_2 subzone throughout the South-Western Province. Bands crowded with *Seminula*, *Lithostrotion*, or *Productus corrugato-hemisphericus* recur again and again.

Fauna of Upper S_2:

Corals:—

Syringopora—6.
Alveolites—6.
Lithostrotion martini Ed. & H., and varieties.—2, 6, 8 (very abundant).
Carcinophyllum θ Vaughan—6, 8.

Brachiopods:—

Productus hemisphericus Sow.—2, 6, 8.
Productus corrugato-hemisphericus including '*P. cora*, mut. S_2,' Vaughan—2, 6, 8 (very abundant).
Papilionaceous *Chonetes*—6, 8.
Seminula ficoides Vaughan and varieties.—2, 6, 8 (very abundant).
Seminula cf. *ambigua* Sow., an S_2 form—2. (Collected by the late Dr. W. B. Gubbin; see 'Bristol Paper,' p. 235.)

Gasteropods:—*Bellerophon*—6.

DIBUNOPHYLLUM ZONE (D).

D_1 :

Eastern District: Pwll-du (5); Limeslade Bay (6), and Mumbles Head (6 *a*); southern end of Colts Hill (Oystermouth); Bishopston Valley (8).

South-Western District: Port Eynon (3).

Corals:—

Syringopora geniculata Ed. & H.—3.
Alveolites septosa (Flem.) Ed. & H.—5.
Zaphrentis ambigua Carruthers (?)—a unique specimen from (3).
Campophyllum aff. *murchisoni* Ed. & H.—6, 6 *a*, 8, 3.
Clisiophylloid *Campophyllum*—5, 3.
Cyathophyllum murchisoni Ed. & H.—5, 3, 8, 6 *a* (extremely abundant).
Lithostrotion martini Ed. & H., and vars.—5.
Lithostrotion junceum (Flem.).—6 *a*.
Koninckophyllid—6.
Diphyphylloid *Cyathophyllum*—3, 6 *a*.
Cyathophylloid *Aulophyllum*—8.
Carcinophyllum θ Vaughan and a variety convergent with *Dibunophyllum* θ—5, 6 *a*.
Dibunophyllum θ Vaughan, and *D.* φ Vaughan—6, 6 *a*, 5, 3, 8.
Dibunophyllum aff. ψ Vaughan—3.

Brachiopods:—

Productus hemisphericus Sow.—5, 6 *a*, 8 (very abundant).
Productus giganteus (Mart.)—5, 3, 6 *a*, 8.
Chonetes (Daviesiella) aff. *comoides* (Sow) Vaughan—5, 8. (See p. 561.)
Athyris cf. *expansa* (Phill.), mut. D_1—6 *a*.

The above fauna is characteristic of D_1 throughout the South-Western Province.

D_{1-2}:

The uppermost beds of the Pwll-du section contain *Dibunophyllum* aff. ψ Vaughan and *Lithostrotion portlocki* (Bronn) Ed. & H. (both of which are D_2 forms), in association with the normal D_1 assemblage.

D_2:

South-Western District: Well exposed in quarries at Port Eynon.

Fauna:—

Corals:—

A narrow *Syringopora.*
Michelinia tenuisepta (Phill.) (near the top).
Alveolites (?).
Zaphrentid and 'Calophyllid.'
Cyathophyllum murchisoni (?).
Lithostrotion irregulare (Phill.) (abundant in the lower part).
Lithostrotion junceum (Flem.) Ed. & H.
Petalaxis portlocki Ed. & H. (common near the top).
Dibunophyllum ψ Vaughan (not common).

Brachiopods:—

Latissimoid *Productus* (common).
Productus cf. *concinnus* Sow. (broad form).
Productus cf. *muricatus* Phill.
Productus scabriculo-costatus (abundant at the very top).
Productus striato-corrugatus.
Papilionaceous *Chonetes* (small form).
Leptæna cf. *distorta* Sow.
Spirifer planicosta (M'Coy).
Martinia cf. *ovalis* (Phill.).
Martinia glabra (Martin).

Bryozoa:—

Fenestella sp. nov.

Note.—Although *Lonsdalia* has not yet been recorded with certainty, the above fauna may be unhesitatingly regarded as characteristic of D_2.

The D_{2-3} Phase:

Eastern District { Oystermouth. { Top of quarry on north of Colts Hill (*a*).
'Black-lias' Quarry (*b*).
Bishopston (road-section in Rottenstones) (*c*).
South-Western District: Port Eynon, above D_2 series) (*d*).

Since this phase was unknown to me when writing the 'Bristol

Paper,' the fauna recorded below is, in the main, new to the South-Western Province.[1] I have consequently devoted the Palæontological Section, almost in its entirety, to descriptions of the most interesting components of this fauna. Reference must, therefore, be made to that section for explanations of the fossil names which compose the following list.

Corals:—

Michelinia tenuisepta (Phill.) (*a, b*).
Amplexus (?) sp. (*b*).
Zaphrentis enniskilleni Ed. & H. (*a, b*).
Zaphrentis oystermouthensis, sp. nov. (*a, b*); common.
Densiphyllum cf. *charlestonense* Thomson (*b*).
Caninia aff. *cornucopiæ*, mut. D_{2-3} (*a, b*).
Caninia (?) sp. (*a*).
Cyathaxonid (cf. *Cyathaxonia* aff. *costata* M'Coy, Vaughan: figured in 'Rush Paper,' pl. xxix, fig. 5) (*a*).

Brachiopods:—

Productus longispinus Sow., var. (*b, c, d*).
Productus sulcatus Sow. (*a, b, c*).
Productus scabriculo-costatus (*b, c*).
Productus corrugatus M'Coy (*b, c*).
Productus aff. *hemisphericus* Sow. (*b*).
Productus edelburgensis Phill. (*b, c*).
Productus margaritaceus Phill. (*b*).
Productus punctatus (Mart.) (*b*).
Productus elegans M'Coy (*b, c*).
Chonetes sp. (*b, c*).
Papilionaceous *Chonetes* (small form) (*b*).
'*Orthotetes*' cf. *crenistria* (Phill.) (*b, c*).
Schizophoria cf. *keyserlingiana* (Dav.) (*b*); form intermediate between *Schizophoria* and *Rhipidomella* (*b*).
Spirifer bisulcatus Sow., var. *oystermouthensis*, nov. (*a, b, c, d*); very abundant.
Spirifer near *increbescens* Hall (*b*).
Spirifer wickensis, sp. nov. (*b*).
Spiriferina insculpta (Phill.) (*b, c*).
Reticularia lineata (Mart.), globular variety (*b, c*).
Martinia glabra (Mart.) (*a, b, c, d*).
Athyris (Cliothyris) globularis (Phill.), and a circular variety.
Camarophoria cf. *crumena* Dav. (*non* Mart.) (*b*).
Camarotœchia[2] aff. *pleurodon* (Phill.) (*b*).

Bryozoa:—

A *Fenestella* and a Monticuliporoid seem both to be distinctive (*b, c*).

---

[1] A return visit, in company with Mr. W. H. Wickes, was therefore undertaken in order to make the list as exhaustive as possible.

[2] The rubbing-down of this, and of several typical specimens of *Rhynchonella pleurodon* Phill. from the Upper Devonian of Wetton, has shown that this species agrees with *Camarotœchia* in possessing a double and camerate septum in the brachial valve (see 'Bristol Paper,' p. 302); *Pugnax* has no septum in this valve.

Trilobites:

The types of *Griffithides barkei* H. Woodw. (*c*) (Geol. Mag., 1902, p. 484) and *Gr. glaber* H. Woodw. (*b*) ('Mon. Brit. Carb. Tril.' pt. ii, Pal. Soc. 1884, p. 40).

Note on the Bishopston Fauna.

The only noticeable differences that distinguish the Bishopston fauna from that of Oystermouth are the absence of Zaphrentids at Bishopston and the predominance there of *Spirifer trigonalis* (Mart.) over *Sp. bisulcatus* Sow. The large number of species common to the two localities demonstrates approximate equivalence of level, and also the Upper D age of both faunas.

Note on the Horizon of the D_{2-3} Beds of Gower.[1]

[Evidence and inference are here set out under localities.]

(i) Bishopston:—

(1) The Rottenstones represent the top of the D_{2-3} series;

(2) The shales immediately above the Rottenstones, and interbedded with the radiolarian cherts, have yielded *Posidoniella lævis*, *Solenomorpha minor*, and *Glyphioceras bilingue*—fossils which Dr. Wheelton Hind identified and considers to indicate a level 'low down in the Pendleside Series.'

It is also important to note that, in shales considerably above the level of those in the Bishopston cutting, *Glyphioceras spirale* (Phill.) is recorded by the Geological Survey.[2]

(ii) The two quarries on Colts Hill, Oystermouth.—The Southern Quarry is in D_1, and there is a continuous series of some 120 feet of massive limestone between it and the base of D_{2-3} in the Northern Quarry. This limestone is very poorly fossiliferous, although it contains a bed crowded with a latissimoid variant of *Productus hemisphericus* Sow. near the base of the Northern Quarry.

Allowing a certain weight to this form and to the small thickness of the limestone series between the quarries, it is evident that the base of D_{2-3} cannot be of later date than D_2 age.

The fauna of the base of the D_{2-3} series in the Colts Hill Quarry cannot be distinguished from that of the Oystermouth Quarry, except for the presence of '*Cyathaxonia*' in the first-named locality. This coral occurs with *Zaphrentis* nr. *oystermouthensis* in the *Cyathaxonia* Beds of the Rush and Loughshinny sequence in County Dublin, and I have already suggested ('Loughshinny Paper' p. 444) that these last-named beds are the equivalent of part of D_{2-3} of Gower and of part of D_2 of the Bristol Area.

(iii) Port Eynon.—Succeeding the massive and typical D_2 limestones at Port Eynon are thinly-bedded limestones and shales of

---

[1] See also § II, p. 495.

[2] Swansea Memoir, p. 25.

'black lias' rock-facies, which are poorly exposed on the foreshore. From these beds we obtained *Productus longispinus* Sow., var., *Spirifer bisulcatus* Sow., var., and *Martinia glabra* (Mart.), var., identical in form with the same varieties from Oystermouth. Hence it is clear that the D_{2-3} fauna is, in part at least, later than that of the D_2 massive limestones.

It is also interesting to observe that *Productus scabriculo-costatus* does not come in at Port Eynon until the very top of the D_2 limestones, and that, in the Bristol Area on the east and at Kidwelly and Pendine on the west, the same form is first met with above the typical D_2 and immediately below the Millstone Grit.

(iv) From the shales at the 'paint-mine,' near Port Eynon, we obtained the following fossils (identified by Dr. Wheelton Hind):—

Posidonomya becheri (Bronn).
Posidoniella lævis (Brown)?
Glyphioceras reticulatum (Phill.).
Glyphioceras bilingue (Salter).

Dr. Hind suggests that, here, we are 'fairly low down in the Pendleside Series.' Since these shales are faulted against the limestone, it is impossible to ascertain their precise position stratigraphically; it can, however, be safely assumed that they lie above the 'black lias' of the foreshore at Port Eynon.

This record, taken in conjunction with the fossils cited from the shales at Bishopston, demonstrates that a Pendleside Phase occurs above the D_{2-3} Phase, just as it does above the *Cyathaxonia* Beds (D_3) of County Dublin.

Table correlating the Upper Avonian of Gower, Bristol, and Rush (County Dublin).

BRISTOL.	GOWER.		RUSH AND LOUGHSHINNY (CO. DUBLIN).
	Port Eynon.	Oystermouth.	
'Millstone Grit.'	Pendleside.		P.
	D_{2-3}.	D_{2-3}.	
D_2.	D_2.		D_3 ('*Cyathaxonia*' Beds).
D_1.	D_1.	D_{1-2}.	D_{1-2} ('*Dibunophyllum*' Beds).
		D_1.	Unknown.

The correlation of the Bristol and Gower sequences with those of Northumberland, Yorkshire, North Wales, the Midlands, etc., is given in the British Association Report, 1909 (Winnipeg), on Lower Carboniferous Zones, p. 187.

VIII. Palæontological Notes [A. V.].

(A) CORALS.

TABULATA.

Syringopora.

Syringopora cf. geniculata Phill., Nicholson, from C_2 (main part).

This is the dominant *Syringopora* of C_2, Gower, and it there takes the place of *Syringopora* cf. *reticulata*, which is the commonest form in C_2–S_1 of the Bristol area.

Description.—Broad and ramulose, with strongly thickened tubes and not numerous connectors. Very numerous, thick, septal spines project from the wall, and almost or quite penetrate the very thick lining of stereoplasm. (The abundance and strength of the septal spines causes a misleading resemblance, in cross sections, to *Lithostrotion junceum*.)

Tabulæ deeply dependent and distant.

Comparison.—*S. geniculata* Phill., Nicholson, 'Tabulate Corals' 1879, pl. x, figs. 4, 4 *a*, & 4 *b*, agrees closely with our species, from which it differs only in degree, namely, it has shorter septal spines, less widely-spaced tabulæ, and is far les ramulose.

Nicholson's conception of *S. geniculata* Phill. differs from the type-figure[1] in the scarcity of connectors, but agrees with Phillips's definition of the species in respect to the ramulose habit ('radiating, often flexuous, branching, round tubes'—Phill. *op. cit.* p. 201).

On the other hand, the accepted connotation of the specific name *geniculata* (compare Ed. & H. 'Monogr. Brit. Foss. Cor.' Pal. Soc. 1852, pl. xlvi, figs. 2 & 2 *a*) disagrees with Phillips's figure in the absence of radiation and branching.

The type of Phillips's species being lost, there seems little hope of obtaining a clear conception of *S. geniculata* from his definition and figure.

ZAPHRENTIDS.

Zaphrentis.

Zaphrentis oystermouthensis, sp. nov. (Pl. XL, figs. 1 *a*–1 *e*.)

Compare *Zaphrentis* aff. *enniskilleni* Ed. & H., Vaughan in 'Rush Paper,' pl. xxix, fig. 2. See also 'Loughshinny Paper' p. 457.

Description.—Form conical and as a rule continuously cornute, 4 to 5 cm. in length. (Fig. 1 *a* illustrates the less common form, which is only bent at the tip.)

External surface practically smooth, except for fine annular striæ and flattened rugæ.

In the calyx:—Fossula on the concave side, very deep, and occupying more than half the diameter of the coral.

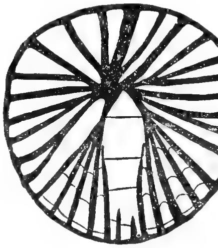
---

[1] 'Geol. Yorkshire' pt. ii (1836) pl. ii, fig. 1.

Major septa very strongly thickened and frequently coalescent; minor septa only developed in the calyx.

Horizontal sections.—In the young stage the horizontal section of the fossula is regularly and broadly oval, and bisected by a strong fossular septum (Pl. XL, fig. 1 *b*).

Fig. 9.—Zaphrentis oystermouthensis, *sp. nov.: section below the calyx, magnified 2 diameters. (Specimen figured in Pl. XL, fig. 1 a.)*



In the adult, where the septa have ceased to increase, the fossula is broadly open near the wall and narrows to the centre, being bounded by a single septum on either side (Pl. XL, fig. 1 *e*).

In intermediate stages the appearance of the fossula depends on whether the section intersects a pair of new septa or not; if it does so, the fossula is contracted in the middle, as in *Z. delanouei*; if it does not, the appearance is much like that of the adult (compare Pl. XL, figs. 1 *c* & 1 *d*).

The septal plan has the following characters (see fig. 9, above):—

(1) A strong thickening of the counter-septum;
(2) Great variation in length and direction of the major septa;
(3) A strong convexity of the longer septa (in the adult) to the generative planes (or 'fossular breaks.')

From (2) and (3) results the characteristic palmate grouping of the septa and the dependent lateral boundaries of the counter series.

Tabulæ (see fig. 10, p. 555).—The tabulæ are broad, strongly depressed in the middle and along the fossula, and gently everted at the wall.

Horizon and localities.—This species is abundant in D_{2-3} of Oystermouth Quarry. A very similar form is rare in the '*Cyathaxonia* Beds' of Rush.

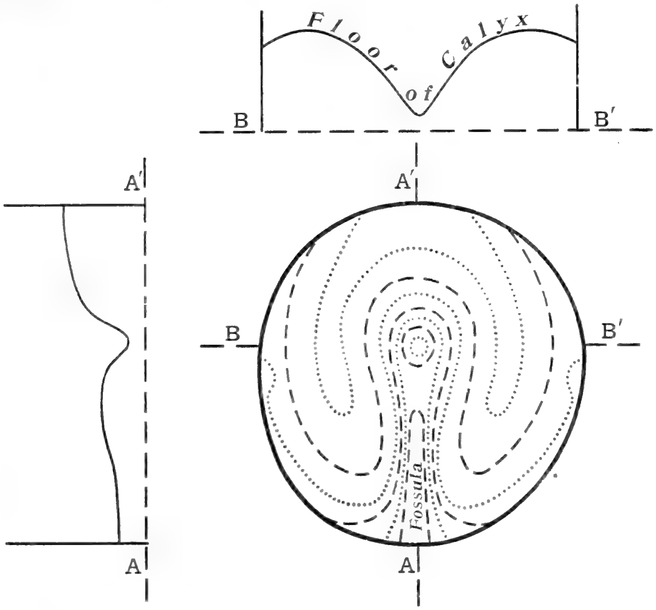
Resemblances and differences.—*Zaphrentis delanouei* Ed. & H. is of much smaller average dimensions, and its dominant form is almost purely conical (only the tip being curved), whereas the usual form of *Z. oystermouthensis* is continuously cornute.

In *Z. delanouei* the counter (anti-fossular) septa in the adult are regularly radial, uniformly thick, and approximately of equal length; whereas in *Z. oystermouthensis* they present a quadripinnate grouping, and are of very unequal thickness.

Comparison with *Z. enniskilleni* Ed. & H.—The type-specimen of *Z. enniskilleni* Ed. & H., represented in Pl. XL, fig. 2, shows how markedly *Z. oystermouthensis* differs in the greater irregularity and thickening of its septa, although agreeing in the general plan of septation and in the position of the fossula.

Evolution of *Z. oystermouthensis*.—Among the Z_1 forms, which may all be attributed to *Z. delanouei* Ed. & H., is one which agrees very closely with the young stage of *Z. oystermouthensis* depicted in fig. 1 *b* (Pl. XL); if this form represents the ancestral member of the gens of *Z. oystermouthensis,* variation has merely increased the size and emphasized the irregularity of the septa in direction and thickness.

Fig. 10.—Zaphrentis oystermouthensis, *sp. nov.: contoured plan of floor of calyx, magnified 2 diameters, and two sections on the same scale across the calyx. (Specimen figured in Pl. XL, fig. 1 a.)*



Caninia.

CANINIA aff. CORNUCOPIÆ Mich., mut. D_{2-3}. (Pl. XL, figs. 3 *a*–3 *c*.)

I have already described the characters of this mutation under the generic title of *Amplexi-Zaphrentis,* in the 'Rush Paper' p. 315 & pl. xxix, fig. 7; and also in a note kindly inserted by Mr. Carruthers in his 'Revision of Carb. Corals' Geol. Mag. 1908, p. 169.

Consequently, it is only necessary here to point out the differences between the Upper Avonian form of the South-Western Province and the Lower Avonian species of the same region (Z_2–γ), an example of which is figured in Pl. XL, fig. 4. These differences are appreciable only in the adult, and by comparison of the average form at the two levels.

The D_{2-3} mutation :—The tabulæ are gently depressed and close-set; the fossular depression starts near the margin. Hence, in a horizontal section, the contours of the tabulæ, between the septa and in the fossular valley, are close-set and nearly parallel.

The thin vesicular wrapping is developed early, and is practically continuous over the whole of the cylindrical portion.

The γ species (= *Caninia cornucopiæ* Mich., emend. Carruthers) Pl. XL, fig. 4:—The tabulæ are well spaced, and the fossular depression starts near the centre. Hence, in a horizontal section, the contours of the tabulæ, between the septa and in the fossula, are few and widely spaced.

The thin vesicular wrapping is developed late and, even in the adult, is seldom present over the greater part of the cylindrical portion.

Occurrence in the South-Western Province.—The γ species is doubtless common at most localities at the top of Z_2 and in C_1, although Burrington (Mendips) and Stackpole Quay (Pembroke) are the only localities which have as yet been thoroughly searched.

At the top of D_2 and in D_{2-3} the upper mutation is usually to be found, and is often abundant. It is almost invariably cylindrical for the greater part of its length, and broader than the '*cornu-bovis*' variant from the Upper Tournaisian (specimens indistinguishable, externally, from that variant are, however, occasionally found).

In Gower, this mutation occurs in D_2 of Port Eynon and throughout D_{2-3} of North Colts Hill Quarry and of Oystermouth Quarry.

In the Bristol area it is a very rare fossil in D_2. In the west of the South-Western Province—Horizon ϵ of Ragwen Point near Pendine—specimens are common, and at Bullslaughter Bay, near Bosheston (South Pembrokeshire), it is very abundant in D_2 in association with *Glyphioceras sphericum* (Martin) and a small *Cyathaxonia*.

Caninia (?) sp. (Pl. XL, fig. 5.)

This coral is remarkable for the extent and slope of the tabulæ, for the shortness of the septa, and the practical absence of a fossula. The tabulæ are flat, and extend almost completely across the corallum; they slope very steeply downwards from the convex to the concave side.

Owing to their high dip, a cross-section cuts several tabulæ; and consequently the interseptal spaces, on the concave side, appear to be vesicular.

Above a tabula the septa are very short and amplexoid without any septal break; underneath a tabula, they are elongated on the concave side and short on the convex side with a small fossular gap. Minor septa are only developed in the calyx.

This species appears to be intermediate between *Amplexus* and *Caninia*—in fact an *Amplexus* above the tabulæ and a *Caninia* below: a *Caninia* in form, an *Amplexus* in calyx.

The few specimens that I have seen from Oystermouth were collected by Mr. Underhill from the base of D_{2-3} in North Colts Hill Quarry.

Mr. H. F. Barke, A.I.C., has collected from γ at Burrington a similar coral having the general form, the short septa, the broad steeply-sloping tabulæ, and the inconspicuous fossula of the species under description. The earlier coral is, however, Amplexoid throughout, and its minor septa are practically undeveloped in the calyx.

Amplexus.

AMPLEXUS (?) sp. (Pl. XL, figs. 6 *a* & 6 *b*.)

Form cylindro-conical, the junction of the cylindrical and conical portions being abruptly marked by an extremely strong growth-halt and by a change of axial direction.

The epitheca has the strong girth-ridges characteristic of *Amplexus nodulosus* Phill., but there are no spines.

The septa are long, widely spaced, and about 20 in number.

In the figured section (fig. 6 *b*) the septa extend much farther towards the centre than is the case in the small Amplexids so common at this level in northern localities (*A. nodulosus* Phill., etc.), and they again differ very remarkably in their inequality. It is, however, to be noted that sections differently situated with regard to the tabulæ exhibit a series of equal septa which fall short of the centre, and only differ from those of *A. nodulosus* in their greater length.

The tabulæ are strong, distant, tall arches, flattened or gently convex above and sharply bent down near the wall.

The species is rare in D_{2-3} of Oystermouth Quarry, where it takes the place of *A. nodulosus*, which is common at the same level in other localities.

This species differs from *A. nodulosus* Phill., de Kon.[1] in its septal plan (as explained above), in its few distant tabulæ, and in the small number of its girth-ridges.

CLISIOPHYLLIDS.

Dibunophyllum.

DIBUNOPHYLLUM θ Vaughan, and an early form of DIBUNOPHYLLUM ψ Vaughan. (Pl. XL, fig. 7.)

The figured specimen is from D_1 of Port Eynon; it shows a cross-section of two cylindrical *Dibunophylla*, side by side.

---

[1] 'Nouv. Rech. Anim. Foss. Terr. Carb. Belg.' 1872, p. 74 & pl. vi, fig. 5.

I. The right-hand specimen presents the typical characters of *Dibunophyllum* θ, namely:—

A circular, ill-bounded central area, which is completely bisected by a somewhat flexuous mesial plate; the general structure of the area is simply reticulate.

A loosely vesicular external area, with a very ill-defined inner boundary.

Extremely short minor septa.

II. The left-hand specimen illustrates the early form of *Dibunophyllum* ψ, with which it agrees in the following characters:—

The cuspidate boundary of the central area.

The suggestion of Aspidophylloid characters: that is (1) the abrupt termination of the mesial plate within the central area; (2) the fact that the lamellæ start from the boundary of the area, and fall short of the mesial plate.

The close-set vesicles of the external area and the well-defined inner wall.

The elongate minor septa, which usually extend completely across the external area.

The differences are mainly of degree only, namely:—

The early form is cylindrical (convergent on *Dibunophyllum* θ); *Dibunophyllum* ψ is conical.

The sharp, cuspidate boundary of the central area and the Aspidophylloid characters are more strongly marked in *Dibunophyllum* ψ.

A purely vesicular peripheral area is practically absent from the D_1 form.

This early form of *Dibunophyllum* ψ is not uncommon at several localities in the South-Western Province.

CYATHAXONIDS.

'CYATHAXONIA' sp.

Compare '*Cyathaxonia*' aff. *costata*, figured in Rush Paper, pl. xxix, fig. 5.

Two poorly preserved specimens, from the base of D_{2-3} in the North Colts Hill Quarry, were collected and kindly presented to me by Mr. Underhill; their matrix is rottenstone. Both specimens show the calyx, and one of them shows, at its lower end, the highly-vaulted under surface of a tabula.

Radiating from the wall are 26 septa, short, thick, and of equal length, except that the fossula is marked by a single short cardinal septum.

The floor of the calyx rises centrally into a tall spear-shaped columella, which is laterally compressed and crested like a helmet; the lateral surfaces of the columella are roughened by the external edges of the numerous close-set longitudinal lamellæ. By rubbing down the columella, the lamellæ are seen to radiate inwards towards the mesial plate which is the downward continuation of the crest.

After further rubbing down, through a very short distance, the section cuts an underlying tabula in a roughly concentric curve, and from this curve a second set of lamellæ radiate inwards towards the mesial plate.

The structure of the columella appears, therefore, to be closely similar to that of a Clisiophyllid, and, in particular, to that of *Carcinophyllum*:—the tall vaulted tabulæ, each buttressed by lamellæ and crested by the mesial plate, are arranged in a series of tents one below, and within, another.

The close approximation of the descending portion of successive tabular vaults forms a thick tubular wall enclosing the entire central cylinder throughout the length of the coral.

Comparison:—The specimen figured in the Rush Paper, and cited above, was derived from the *Cyathaxonia* Beds of Bradbourne in Derbyshire; similar forms, less well preserved, are common at the same level at Rush.

The structural plan is essentially similar to that of the Gower specimens.

By rubbing down the Bradbourne specimen through a complete tabular interval, it was demonstrated that the mesial plate is not continuous through the tabulæ, but that it starts afresh above each tabula as a crest, and extends to the under surface of the next tabula above; the lamellæ apparently exhibit the same phenomenon. The resemblance to the central structure of Clisiophyllids is, therefore, extremely close.

Specific differences from the Gower form are obvious:—In the Bradbourne specimen there is a narrow peripheral ring of vesicles and the lamellæ are much stronger and more closely set than in the Gower specimens. In both these characters there is a still closer approach to structures characteristic of *Carcinophyllum*.

(B) BRACHIOPODS.

PRODUCTIDS.

Productus.

Productus sulcatus Sow. (Pl. XLI, figs. 1 *a* & 1 *b*.)

Sowerby, 'Min. Conch.' vol. iv (1823) pl. cccxix, fig. 2.

The holotype of the species is preserved at the British Museum (Natural History) in the Sowerby Collection; it was obtained from Derby. The same form is common in Yorkshire at the top of the Carboniferous Limestone.

The specimen here figured is from D_{2-3} of the Oystermouth Quarry, where the species is not common.

Description:—The pedicle-valve has the following striking characters:—

> Form cylindrical and of quadrate cross-section. Umbonal region parallel to the marginal, and therefore invisible in a 'back view'; the two regions are united by a high vault. Strong reticulation on the umbonal region. Coarse, tall, marginal ribs separated by deep furrows (whence the specific name). Cylindrical wings strongly projecting, and each ornamented by two rows of spines, respectively along and oblique to the hinge-line.

The holotype of *Productus sulcatus* Sow. has a shallow median sinus, whereas the Oystermouth specimen is merely flattened in the median region.

Comparison:—*Pr. costatus* J. de C. Sow., 'Min. Conch.' vol. vi (1829) pl. dlx, fig. 1, differs in possessing the following characters:—

> Form broad and flattened. Both umbonal and marginal areas are visible in a 'back view,' and a vault is undeveloped. Coarse marginal ribs, which are remarkably flattened. Strong development of spines on the wing-ridges. Deep, narrow, median sinus.

Evolution:—The strength of the reticulation of the umbonal region, the thickening of the marginal ribs, and the development of spine-ridges are characters which commonly indicate phylogenetic old-age. It seems probable that *Pr. sulcatus* is derived from some such form as the specimen in the Sowerby Collection which is doubtfully identified with *Pr. antiquatus* Sow., 'Min. Conch.' vol. iv, pl. cccxvii, fig. 5; whereas *Pr. costatus* has probably resulted, by parallel development, from *Pr. antiquatus* Sow., *loc. cit.* fig. 1.[1]

PRODUCTUS (MARGINIFERA) LONGISPINUS Sow., var. (Pl. XLI, figs. 2 *a* & 2 *b*.)

The predominant form of this species in D_{2-3} of the Oystermouth Quarry agrees with *Productus setosus* Phill.,[2] var. *tissingtonensis* Sibly, Q. J. G. S. vol. lxiv (1908) p. 77 & pl. i, figs. 6 *a*–6 *b*.

The most striking character of this variant—namely, the large central and marginal rib in the pedicle-valve—is well shown in Dr. Sibly's figures. Two further points are illustrated in the plate which accompanies the present paper:—

> Pl. XLI, fig. 2 *a*—a partial cast of the interior of the brachial valve—shows a marginal groove, representing a ridge surrounding the muscular region; this is the essential character of the genus *Marginifera* of Waagen.
>
> Pl. XLI, fig. 2 *b*—a pedicle-valve—shows the sharply-raised, collar-like termination of the cylindrical wing.

(The structural exaggerations here noticed are probably no more than indications of phylogenetic old-age, for they occur also in other groups, as, for example, in *Pr. concinnus*.)

This variety is remarkably widespread in the upper part of the *Dibunophyllum* Zone throughout the British Isles.

---

[1] I cannot distinguish fig. 1 from the figure of *Pr. semireticulatus* (Mart.) in 'Petrificata Derbiensia' 1809, pl. xxxii, figs. 1 & 2. If, therefore, *Pr. antiquatus* Sow. is legitimately retained in addition to *Pr. semireticulatus* (Mart.), it must denote such a form as that of Sowerby, pl. cccxvii, fig. 5. On the other hand, if it be considered that Sowerby, by his query, rejected Martin's species as insufficiently described and figured, and proposed the new specific name *antiquatus* in its stead, fig. 1 becomes the holotype of *Pr. antiquatus* Sow., and *Pr. semireticulatus* (Mart.) dies out. In my use of *Pr. antiquatus* Sow. I have adopted the first-mentioned course.

[2] If *Productus setosus* Phill. ('Geol. Yorks.' pt. ii, 1836, pl. viii, fig. 9) be separated from *Pr. longispinus* Sow. (refigured in 'Davidson,' pl. xxxv, fig. 5), the Oystermouth form must be regarded as a variant of the small globose type of Sowerby's species, rather than of Phillips's large and sulcate type. On the other hand, *Pr. setosus* Phill., var. Phill. (*op. cit.* pl. viii, fig. 17) agrees closely in convexity and ribbing with our variant.

Chonetes.

CHONETES sp. (Pl. XLI, figs. 3 *a* & 3 *b*.)

Circumference rectangular, with nearly square cardinal angles. Ribbing fine and close-set.

In the pedicle-valve the form is flattened-convex, with the maximum rise at half-way across the valve. The strong growth-halt and the thickened marginal band below it cause a deep marginal depression in the cast. A shallow marginal median sinus and a corresponding median inflection of the circumference are occasionally developed.

This species is very common at certain levels in D_{2-3} of Oystermouth and Bishopston in Gower. It also occurs abundantly farther west in the South-Western Province, at Ragwen Point near Pendine, at approximately the same level (namely, Horizon ϵ).

Daviesiella.

The essential character of *Daviesiella* Waagen as exhibited in the genotype *D. llangollensis* (Dav.) is the presence of an additional pair of adductors in the large valve ('Davidson' pl. lv, fig. 9—scars lettered C).

The large Productoid *Chonetes* from C—*Chonetes* cf. *comoides*—has no additional adductors; whereas, in the Productoid *Chonetes* from D—*Chonetes (Daviesiella)* aff. *comoides*—these scars are very conspicuous.

STROPHOMENIDS.

'ORTHOTETES' cf. CRENISTRIA (Phill.). (Pl. XLI, fig. 4.)

Description.—Hinge-line less than the width of the shell; area asymmetrical. Brachial valve strongly convex as a whole, but flattened in the neighbourhood of the beak.

The radial ornament is strong and markedly periodic.

The concentric fine, close-set growth-lines produce a delicate 'crenistriation' on the ribs and a reticulation of the narrow flat interspaces; there are a few well-marked growth-halts. Dental plates on a simple Strophomenoid plan.

Comparison.—In area and ornament this form approaches very closely to *O. crenistria*; by its marked convexity[1] and more strongly periodic ribbing it is easily distinguished.

This form is not uncommon in the Oystermouth beds (D_{2-3}).

---

[1] The figured specimen is from thin shales and is crushed flat; specimens showing the strong convexity of the brachial valve were, however, obtained.

SPIRIFERIDS.

Spirifer.

SPIRIFER BISULCATUS Sow., var. OYSTERMOUTHENSIS, nov. (Pl. XLI, figs. 5 *a* & 5 *b*.)

This variant differs from Davidson's figure[1] of the type of the species ('Davidson,' pl. vi, figs. 6–9) in having:—

(1) Broad scarped ribs and a gently convex mesial fold, but little differentiated from the flanks;
(2) A flatter and more transverse form; and
(3) The cardinal region almost smooth.

It is extremely abundant in D_{2-3} of Oystermouth, but rare in D_{2-3} of Bishopston.

Comparisons.—*Spirifer calcaratus* M'Coy[2] (Pl. XLI, fig. 5 *c*) differs in its spine-like wings, unequally developed on the two sides. This species is common in D_{2-3} of Pateley Bridge (Yorkshire).

Spirifer bisulcatus Sow. var., Q. J. G. S. vol. lxiv (1908) pl. 1, figs. 3 *a* & 3 *b*, differs in its small size and want of bilateral symmetry; it is common in Lower P of Loughshinny (Co. Dublin).

Ornament.—The intersection of radial and concentric ornament produces the characteristic 'twilling' shown in fig. 5 *b*. This type of ornament is common to all the forms mentioned above.

SPIRIFER near INCREBESCENS Hall. (Pl. XLI, fig. 6.)

Compare *Sp. increbescens* in Hall & Clarke, 'Palæont. New York,' vol. viii, pt. ii (1894) pl. xxx, figs. 27–30 (specimen from Chester Limestone).
Compare also the type of *Sp. bisulcatus* Sow., as refigured by Davidson (pl. vi, figs. 6–9).

Our species only differs from *Sp. increbescens* in its smaller size (27 mm. wide as against 38 mm.), and probably also in the smaller degree of differentiation of the median fold from the flanks.

The shagreen-like ornament is also not so conspicuous as in fig. 30 of the American species.

The differences from the type of *Spirifer bisulcatus* Sow. are more numerous, namely:—

(1) The smaller size.
(2) The tall, angular median fold is composed of a narrow, central, grooved rib and two flat broad ribs, which form the steep slopes of the fold on either side; the valve-intersection is strongly deflected into a tall domed arch. In *Sp. bisulcatus* the median fold is gently and continuously convex from flank to flank, and the deflection is semicircular.

---

[1] There is considerable doubt whether the imperfect specimen in the Sowerby Collection at the British Museum (Natural History) is actually the holotype of *Spirifer bisulcatus* Sow.; if so, both Sowerby and Davidson have erroneously restored the mesial fold.

[2] 'Synopsis Carb. Foss. Ireland' 1844, pl. xxi, fig. 3; refigured in 'Davidson' pl. vii, fig. 4.

(3) The slopes of the median fold pass gradually into the flanks, whereas, in *Sp. bisulcatus*, the fold is sharply separated from the flanks by a change in curvature and by two strongly marked furrows (to the presence of which[1] the species owes its specific name).

This species (or variant) is not uncommon in D_{2-3} near the top of Oystermouth Quarry. Its small, convex, *pinguis*-like appearance readily distinguishes it from the broad flattened *Sp. bisulcatus*, var. *oystermouthensis*, which is the predominant form.

SPIRIFER WICKENSIS, sp. nov. (Pl. XLI, fig. 7.)

Compare the following forms figured in 'Davidson':—
'*Sp. duplicicosta*,' var., pl. iv, fig. 4 (from Park Hill).
'*Sp. grandicostatus*,' pl. vii, figs. 8–11 (from Bolland).
Also compare:
Sp. cameratus Morton, var. figured in Hall & Clarke, 'Palæont. New York,' vol. viii, pt. ii (1894) pl. xxxii, fig. 12, from 'Coal-Measures.'[2]
See also *Sp. striatus*, var., in Q. J. G. S. vol. lxii (1906) p. 310 (from the Curkeen Limestone).

Description.—Cardinal angles often dissimilar, as in the Bolland specimen cited above.

Median fold bounded by two deep furrows.

Ribs few, but tall, angular, and separated by deep furrows; the striking and irregular manner in which they fork, so that the branches often diverge very widely, makes the species easy of recognition.

In so far as the type of ribbing is concerned, this is an old-age character that can be arrived at by structural change within distinct gentes. For example:—

(1) The form in the Curkeen Limestone (Co. Dublin) is clearly a derivative from a striate stock, since it is connected with more normal members of that stock by intermediate forms.
(2) The American variant is derived from a stock having the ribs in fascicles, and has been evolved by the blending of each fascicle into a single strong rib.
(3) It is probable that in very many cases this type of ribbing has been arrived at from a variant of *Sp. bisulcatus* with coarse ribs, in which the characteristic forking is already initiated near the margin.

Hence this species is rather of the nature of a circulus than of a true species; it has, however, an important stratigraphical value, since it is widely distributed and is as yet unknown below D_2.

In the Bristol area *Sp. wickensis* occurs abundantly in D_2 at Wick (whence the specific name) and, somewhat rarely, at Wrington and in the Avon section at the same level.

In Gower it is a rare associate of the D_{2-3} fauna, and has been found in Oystermouth Quarry.

---

[1] Davidson seems to have regarded the two grooves on the fold itself, to which the fold owes its tripartite character, as the reason for its specific name. Sowerby, however, states clearly that the character recorded in the name is the separation of the fold from the flanks by two deep furrows.

[2] Hall & Clarke assign to the 'Coal-Measures' British specimens obtained from Upper D (for instance, the types of the species:—*Spirifer striatus*, *Reticularia lineata*, *Martinia glabra*, *Productus longispinus*).

In Northumberland it has been found by Mr. Stanley Smith at the level of the Acre Limestone (probably of D_{2-3} age); it is there associated with a brachiopod fauna similar to that of Wick and with corals of Oystermouth facies.

The form from the Curkeen Limestone of County Dublin also occurs at approximately the same level.

Martinia.

MARTINIA GLABRA (Mart.), varietal form.

Compare *M. glabra*, mut. P., 'Loughshinny Paper' p. 468 & pl. l, fig. 8.

This variety differs from Martin's type in its more equidimensional form and in the more flattened brachial valve. The cast of a pedicle-valve shows the absence of dental plates, and the presence of strong ridges which indicate deep furrows in the interior of the valve—characters which are distinctive of the genus, and are equally well exhibited in *M. ovalis* (Phill.).

Compared with the later mutation from P of Loughshinny, the muscular scars are very indistinct, whereas they are deeply impressed in the Loughshinny form.

This variety occurs throughout the Oystermouth Series (D_{2-3}); it is rare immediately above the massive limestone of North Colts Hill Quarry, abundant in Oystermouth Quarry, and rare again in the Bishopston cutting.

ATHYRIDS.

Athyris.

ATHYRIS (CLIOTHYRIS) GLOBULARIS (Phill.). (Pl. XLI, fig. 8 *a*.)

The holotype of Phillips's species is preserved at the British Museum (Natural History) in the Gilbertson Collection; it bears clear indication of the former presence of fringed expansions in the fine imprints which they have marked upon the valve. Hence this species may be regarded as a dwarf and late representative of the gens of *A. glabristria*, with which it agrees precisely in form and in the strongly developed beak.

The Oystermouth specimens only differ from Phillips's type of *A. globularis* in the preservation of portions of the actual fringes. These expansions are very close-set, and the 'fringe' starts immediately at the suture-line with the valve.

Specimens are common at one level in D_{2-3} of Oystermouth Quarry, and the species is widely spread at the top of the limestone-massif in the Midlands and South Yorkshire.

Comparison with *Athyris (Cliothyris) roissyi* (L'Éveillé), Vaughan (figured in this paper, Pl. XLI, fig. 8 *b*).—The Bristol species is abundant in Km and persists into Z. It differs from *A. globularis* in its non-transverse form, in the upright and small beak, the well-spaced principal expansions, and the existence of a narrow unfringed basal portion at the line of attachment of each expansion.

Comparison with *Athyris roissyi* (L'Éveillé).[1]—The figures of L'Éveillé's type depict a shell of more or less transverse form with a large beak and perforation, a well-marked median fold and strong distant growth-halts. If we accept the tacit assumption, made by both L. G. de Koninck and T. Davidson, that the valves were ornamented with fringed expansions (neither mentioned in L'Éveillé's text nor indicated in his figures), L'Éveillé's species can be well matched by the Z_2 form of '*Cliothyris glabristria*' in the South-Western Province. This conclusion, if recognized,[2] would involve the following changes of nomenclature:—

'*A. glabristria*, mut. Z_2' becomes *A. roissyi* (L'Éveillé).

'*A. roissyi*' of Km and Z becomes a new species, on account of its difference of form and beak (see Pl. XLI, fig. 8 *b*).

Athyris globularis stands, since it is differentiated from the above forms by the closeness of its expansions and by the fact that they are completely fringed.

IX. SUMMARY OF PALÆONTOLOGICAL SECTIONS.

(*a*) The existence of a *Modiola* phase at the base suggests conformity to the underlying Old Red Sandstone; this conformity has been demonstrated by Mr. Dixon in North-Western Gower.

(*b*) The zones Z, C, S and D contain faunal assemblages identical with those of the same zones in the Bristol Area.

It is, however, interesting to note that small *Zaphrentes* of Lower Avonian aspect are abundant just above the *Caninia* Oolite, in association with *Cyathophyllum* ϕ and *Michelinia grandis*.

(*c*) The faunal evidence suggests that the lower limit of the D_{2-3} phase lies within D_2 of Bristol, but that the upper limit of the phase lies above that subzone and within the 'Millstone Grit' of the Bristol sequence.

(*d*) The upper part of C_2 is so closely related faunally with the overlying Lower *Seminula* Zone, that it is impossible to refer these two subzones to different divisions of the Carboniferous Limestone.

(*e*) The most important coral and brachiopod groups discussed in the paper are:—

Zaphrentis oystermouthensis.
Productus sulcatus and *Productus costatus.*
Forms included in the group of *Spirifer bisulcatus.*
Athyris globularis and *A. roissyi.*

I have received much help from the following geologists, and to them I tender my heartiest thanks:—Mr. R. G. Carruthers, Dr. Wheelton Hind, Dr. F. A. Bather, Mr. J. W. Tutcher, and Mr. W. H. Wickes.

---

[1] Mém. Soc. Géol. France, vol. ii (1835) pl. ii, figs. 18–20.

[2] L. G. de Koninck was quite aware of the fact that *Athyris roissyi* had been wrongly identified; but he suggested that no change should be made, in order to avoid confusion. See Ann. Mus. Roy. Hist. Nat. Belg. vol. xiv, pt. 6 (1887) pp. 85. 86.

EXPLANATION OF PLATES XXXVIII–XLI.

Plate XXXVIII.

Fig. 1. 'Pitted' limestone in D_1, Tor-gro (North-Western Gower). A steeply-dipping, weathered bedding-plane. The bag near the right lower corner affords a scale. The limestone is a pseudobreccia, and shows the usual rough surface. (See pp. 490 & 499.)

Fig. 2. Undolomitized pseudobreccia in D_1, slightly weathered, Tor-gro. The dark angular 'fragments' are well defined. Dolomite is absent, from both 'fragments' and 'ground-mass'; the amount of argillaceous impurity is very slight. (See pp. 507 *et seqq.*)

Plate XXXIX.

Partly dolomitized pseudobreccia in D_1, Port Eynon (South-Western Gower). Microscope-section × 8 diameters. The dense material is unaltered 'ground-mass'; the less cloudy, much more foraminiferal areas, at the top, bottom, and left, are the recrystallized 'fragments'; the rhombohedral crystals, many with a diagonal cross, in the 'ground-mass' are dolomite. (See pp. 507 *et seqq.*)

Plate XL.

Upper Avonian corals from the *Cyathaxonia* Phase (D_{2-3}) of Oystermouth, Gower (together with certain forms for comparison).

Figs. 1 *a*–1 *e*. *Zaphrentis oystermouthensis*, sp. nov. (p. 553). Fig. 1 *a*, external and calicular view, natural size. Base of D_{2-3}, North Colts Hill Quarry. Collected by Mr. Underhill. (For septal plan and curvature of tabulæ in this specimen, see text-figs. pp. 554 & 555.) Figs. 1 *b*–1 *e*. All from D_{2-3}, Oystermouth Quarry ('Black Lias'). Fig. 1 *b*, a very young form, × 2¼. Fig. 1 *c*, intermediate stage of the same specimen, × 1¼. Fig. 1 *d*, intermediate stage of another specimen showing differences due to the position of the section with regard to new septa. Fig. 1 *e*, adult stage, × 1¼.

Fig. 2 (for comparison). *Zaphrentis enniskilleni* Ed. & H. (p. 554). Natural size. The holotype of the species. [*Olim* Coll. Geol. Soc., R. 5460.—Now in the Museum of Practical Geology.] Lough Gill (Co. Sligo).

Figs.[1] 3 *a*–3 *c*. *Caninia* aff. *cornucopiæ* Mich., mut. D_{2-3} (p. 555). Three sections from the same specimen, D_{2-3} of Oystermouth Quarry. Fig. 3 *a*, young stage, × 2·7. Fig. 3 *b*, intermediate stage, × 1¼. Fig. 3 *c*, adult stage, × 1¼.

Fig.[1] 4 (for comparison). *Caninia cornucopiæ* Mich., Carruthers (p. 556). Section, × 1¼. Stackpole Quay, Pembroke. Horizon γ.

Fig. 5. *Caninia (?)* sp. (p. 556). Natural size. Base of D_{2-3}, North Colts Hill Quarry. Collected by Mr. Underhill.

Figs. 6 *a* & 6 *b*. *Amplexus* sp. (p. 557), D_{2-3} of Oystermouth Quarry. Fig. 6 *a*, external view, × 1¼. Fig. 6 *b*, section, × 1·2.

Fig. 7. *Dibunophyllum* θ Vaughan (to right) and *Dibunophyllum* aff. ψ Vaughan (to left), slightly reduced (× ·94). D_1 of Port Eynon (p. 558).

Plate XLI.

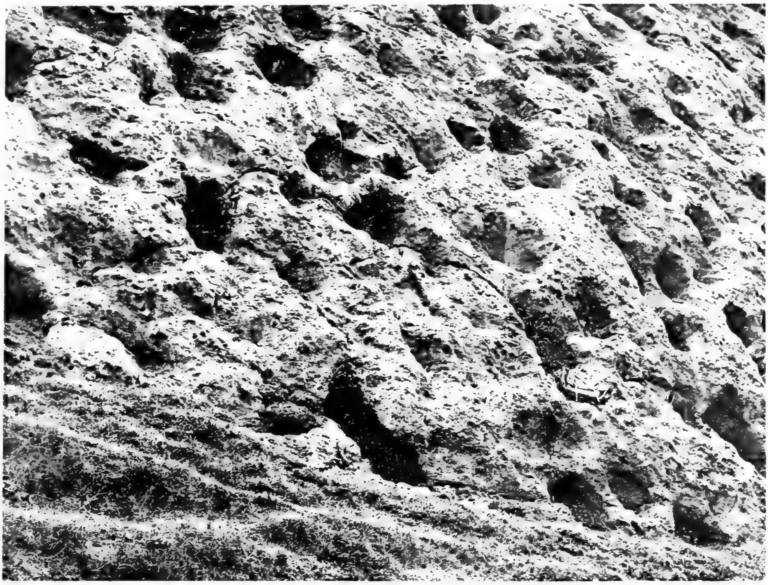
Upper Avonian brachiopods from the *Cyathaxonia* Phase (D_{2-3}) of Oystermouth and Bishopston, Gower (together with certain forms for comparison).

Figs. 1 *a* & 1 *b*. *Productus sulcatus* Sow. (p. 559). Natural size. D_{3-3} of Oystermouth Quarry. Fig. 1 *a*, pedicle-valve, rostral view. Fig. 1 *b*, pedicle-valve, marginal view.

---

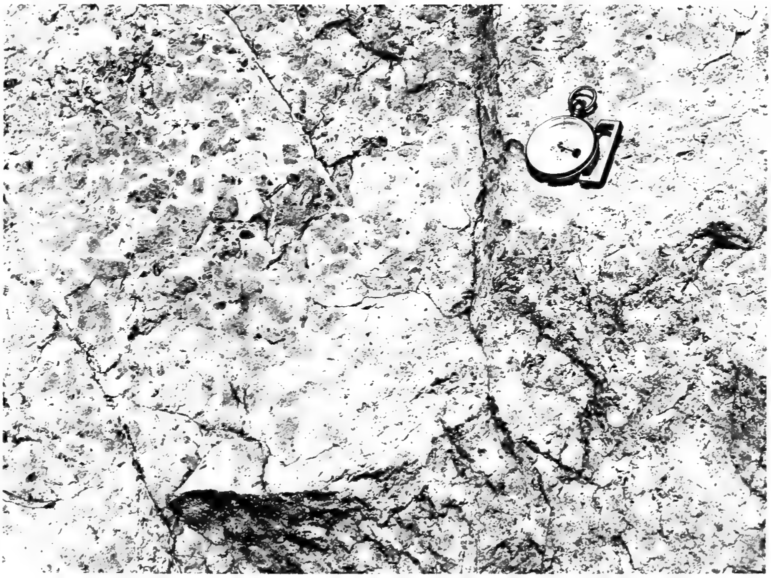
[1] In figs. 3 *b* and 3 *c* the fossula lies to the right of the plane of symmetry for the external surface; figs. 3 *a* and 4, in which the fossula lies in the plane of symmetry, have been set obliquely so as to facilitate comparison.

FIG. 1.—'PITTED' LIMESTONE IN D_1, TOR-GRO (NORTH-WESTERN GOWER).



T. C. Hall, Photo. (Geol. Surv. Colln.).

FIG. 2.—UNDOLOMITIZED PSEUDOBRECCIA IN D_1, SLIGHTLY WEATHERED, TOR-GRO.



T. C. Hall, Photo. (Geol. Surv. Colln.).

Bemrose Ltd., Collo., Derby.

E.E.L.D., Photo. *Bemrose Ltd., Collo., Derby.*

PARTLY DOLOMITIZED PSEUDOBRECCIA IN D_1, PORT-EYNON (SOUTH-WESTERN GOWER), × 8 DIAMETERS.

Fig. 1b.

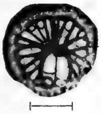


Fig. 1c.

Fig. 1d.

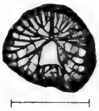
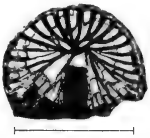


Fig. 1e.



* Fig. 2.

compare

Fig. 1a.

Fig. 6a.

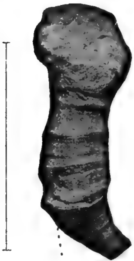


Fig. 6b.

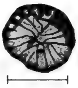


Fig. 3a.

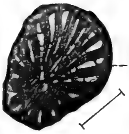


Fig. 3b.

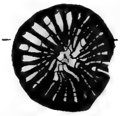


Fig. 3c.

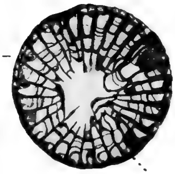
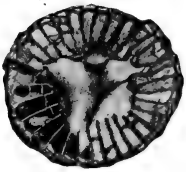


Fig. 5.

compare

Fig. 7.

* Fig. 4.



J. W. Tutcher, Photo.

Bemrose Ltd., Collo., Derby.

AVONIAN CORALS FROM D_2 AND D_{2-3} GOWER.
(* COMPARATIVE FORMS.)

Fig. 1a.

Fig. 2a.

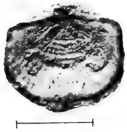


Fig. 2b.

Fig. 1b.

Fig. 4.

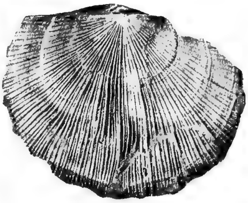


Fig. 3a.

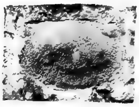


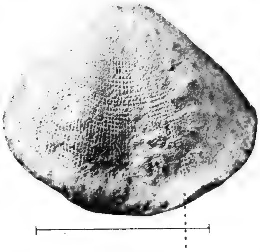
Fig. 5b.

Fig. 3b.

Fig. 5a.

Fig. 7.

Fig. 8a.



compare

* Fig. 5c

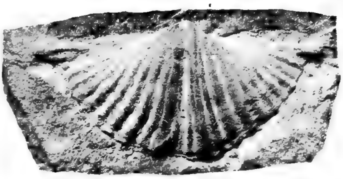
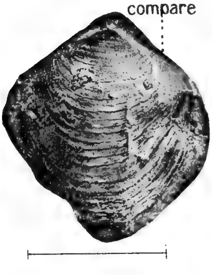


Fig. 6.

* Fig. 8b

compare



J. W. Tutcher, Photo.

Bemrose Ltd., Collo., Derby.

AVONIAN BRACHIOPODS FROM D_{2-3} GOWER.

(* COMPARATIVE FORMS.)

Figs. 2 *a* & 2 *b*. *Productus longispinus* Sow., var. (p. 560). D_{2-3} of Oystermouth Quarry. Fig. 2 *a*, cast of interior of brachial valve, × 1·5; Fig. 2 *b*, pedicle-valve (showing wing), × 1·6.

Figs. 3 *a* & 3 *b*. *Chonetes* sp. (p. 561), natural size. Fig. 3 *a*, cast of pedicle-valve; D_{2-3} (top), Bishopston. Fig. 3 *b*, pedicle-valve from D_{2-3} of Oystermouth Quarry.

Fig. 4. '*Orthotetes*' cf. *crenistria* (Phill.) (p. 561). Brachial valve and area, natural size. D_{2-3} of Oystermouth Quarry. [The specimen is crushed, and does not show the strong convexity of the valve.]

Figs. 5 *a* & 5 *b*. *Spirifer bisulcatus*, var. *oystermouthensis* nov. (p. 562). Fig. 5 *a*, pedicle-valve, natural size. D_{2-3} of Oystermouth Quarry. Fig. 5 *b*, portion of a brachial valve, enlarged to show ornament. Same locality.

Fig. 5 *c* (for comparison). *Spirifer calcaratus* M'Coy (p. 562), natural size; a pedicle-valve from D_{2-3} of Lolley Scar Quarry, near Pateley Bridge (Yorkshire).

Fig. 6. *Spirifer* nr. *increbescens* Hall (p. 562), natural size; a brachial valve from D_{2-3} of Oystermouth Quarry.

Fig. 7. *Spirifer wickensis*, sp. nov. (p. 563), natural size, a pedicle-valve from D_{2-3} of Oystermouth Quarry.

Fig. 8 *a*. *Athyris (Cliothyris) globularis* (Phill.) (p. 564), a pedicle-valve, × 1·5. D_{2-3} of Oystermouth Quarry.

Fig. 8 *b* (for comparison). *Athyris (Cliothyris) roissyi* of the 'Bristol Paper.' Beak and brachial valve, × 1·6 (p. 564). Km ('*Modiola* phase') of the Avon Section.

Discussion.

Dr. A. Strahan observed that this region was one which called especially for combined stratigraphical and palæontological work. The Carboniferous Limestone Series presented a succession of stages in development. The fullest development was exhibited in the southernmost occurrences, as regarded both the sequence and the thickness of zones. A second stage, showing an incomplete sequence and considerable attenuation, with indications of near-shore origin, was presented along parts of the margin of the coalfield. Lastly, in the northernmost occurrences, near Abergavenny and at Pen-cerig-calch, the series dwindled away to 100 feet or less, while in Pembrokeshire it was wholly overstepped. The inference followed that the coast-line ran through Pembrokeshire, and not far north of Abergavenny. Traverses made at right angles to the coast-line, and comparisons of these various stages of development, could not fail to yield results of the greatest interest. The only other district where such a traverse was possible, lay on the northern side of this same Carboniferous land-area, where the Limestone Series could be followed continuously through Denbighshire to its disappearance in Shropshire. That the radiolarian cherts were of shallow-water origin seemed obvious, nor, so far as he was aware, was there evidence of deep water in any part of the Limestone Series: sedimentation or formation of organic deposits seemed to have kept pace with subsidence so nearly that the water was generally shallow. But he was unable to follow the Authors in their identification of lagoon-phases. He enquired whether further evidence had been obtained for identifying and defining the *Posidonomya* Zone. The change of fauna at the base of the radiolarian cherts

was most pronounced, but the upward limit of a '*Posidonomya* Zone' was extremely vague.

The PRESIDENT (Prof. WATTS) congratulated the Authors on the number of issues that they had raised, and on the discussion to which the paper had given rise. He agreed with Dr. Strahan that the South Wales limestone outcrops afford an unrivalled opportunity for the study of the broad variations occurring in a formation throughout its geographical extent: the extent and continuity of the South Wales sequence being far more favourable than the meagre outcrops north of the Midland barrier. He referred to the difficulty in finding modern parallels for the lagoon conditions postulated in the paper, which required wide extent of shallow water, abundance of organisms, and yet freedom from clastic material. Coral-reefs presented almost the only example of such conditions to be observed at the present day. He deprecated too much controversy on the application of Belgian subdivisions to British strata, until the exact extent and character of these subdivisions had been again checked in their country of origin.

Mr. R. H. TIDDEMAN said that he was much pleased with a paper which dealt with so many points of interest. He agreed with the Authors that many of the limestones of Gower had been formed in shallow waters; indeed, when mapping the ground, he thought it probable that the oolites had been formed under æolian conditions. Referring to the term 'lagoon' so much employed, he wished to ask Mr. Dixon whether he had seen anything in the area at all resembling a barrier-reef or reef-knolls, such as the speaker had found in the North of England: he himself had failed to see anything similar in Gower. He was satisfied with the identification of the 'Black Lias' of Oystermouth with the Bishopston white rottenstones, and mentioned that the former, when exposed for a short time to the weather, became covered with a white powder. He believed that the shales above the cherts represented the 'Bowland Shales' (of Phillips), a name which had priority over the Pendleside Shale of a later author.

Mr. A. L. LEACH remarked that the rocks formed under 'shallow-water' conditions appeared to be of great importance in the area described by the Authors, but the application of the definite term 'lagoon-phase' to the conditions under which these sediments were deposited seemed to need further justification. The Authors apparently did not claim a coral-reef origin for any of the rocks described, and the oceanic atoll-lagoons were therefore rightly excluded, as also those coastal lagoons which were bounded seawards by coral-reefs, since neither in Gower nor, so far as his observations went, in Pembrokeshire, were there any limestones of coral-reef origin. Lagoons bounded seawards by islets or by submarine banks were, he thought, usually associated with river-mouths, and were necessarily adjacent to land. Deposits formed in such lagoons would show, he thought, some unconformity with the boundary-deposits, and moreover terrigenous material would probably be present. He had not observed any deposits in the adjacent Pembrokeshire area that could be assigned to lagoons of this type.

The sudden change from the 'calcite-mudstones' of S_2 to the limestones with a deep-water fauna of D_1, as seen at Lydstep in Pembrokeshire, was difficult to reconcile with the suggested lagoon-formation of the 'calcite-mudstones.'

Dr. T. F. Sibly remarked that numerous interesting questions had been raised by this paper. Obviously, a careful study of the evidence would be necessary, in order to appreciate the Authors' conclusions with regard to 'complete cycles of intermittent change,' arrived at by comparing the sequences of lithological types in the three districts. The speaker, however, pointed out that, in view of the small extent of the area under consideration, and the distinctly shallow-water facies of the Avonian as a whole in this area, correlation of movements of the sea-floor in different parts of this area with similar disturbances in different parts of the much larger Bristol area, must be open to considerable error. He asked Mr. Dixon for a definition of the distinctive lithological facies of a 'lagoon-phase.'

It would have been instructive to hear a summary of the special features of the faunal succession in this area. The Avonian fauna appeared to have maintained, on the whole, its normal progression, despite remarkable vicissitudes. With regard to the very wide question of the limiting horizon between Lower and Upper Avonian, was this area, which clearly suffered a maximum of disturbance, a favourable one in which to deal with the question on a faunal basis? The description of the D_2–D_3 phase of the *Dibunophyllum* Zone would doubtless furnish many important facts, and would be especially valuable to those interested in the difficult subject of the correlation of the highest Avonian beds in different areas.

Mr. J. H. Collins regretted that the Authors had not supplied a cross-section, and that no statements had been made as to the thicknesses of the various zones and their subdivisions.

Mr. Cosmo Johns welcomed this account of the lithology and physiographic conditions of deposition of the Carboniferous Limestone in a most interesting district. The Authors' careful observations confirmed the evidence obtained in other areas, and demonstrated the shallowness of the Lower Carboniferous Sea. The non-appearance of dolomites at horizons where, from the evidence of shallowing, they would be expected, might be explained if a critical temperature rather than depth be the factor determining their occurrence. It would appear that the Authors, by 'lagoon-phase,' simply meant partly land-locked shallow waters, free from disturbance by currents. In such restricted areas the water might easily be appreciably warmer than in the outer sea, and thus dolomites for this reason might have a local development only. This suggestion could be put to experimental proof without much difficulty, and temperatures near 30° C. would, from such evidence as is available, seem most promising. He regretted the absence of Dr. Vaughan, in view of the important faunal considerations that arose out of the work done in the area.

Mr. G. W. Young enquired whether the Authors had formulated any theory as to the cause of the frequent oscillation of the sea-

bottom which they believed had taken place; and also whether their suggestion that a considerable deepening occurred at the close of the S_2 lagoon-stage was compatible with the presence, in the succeeding deposit, of a 'thin coaly layer.' As this, in one portion of the district, was accompanied by an underclay, it seemed to present a difficulty.

Mr. A. WADE compared these beds with some which had been forming quite recently at the northern end of the Red Sea. Here, there was a very shallow platform fringing the Eastern Coast, and running out to sea for upwards of 20 miles. A series of limestones could be traced on the islands from the edge of the platform to the mainland. The changes which took place in the physical characters of these limestones might clear up the difficulty that the Authors had with the limestones of the *Seminula* Zone, which were dolomitic in the south-west of Gower but were not so in the north-west. They were, however, entirely oolitic in this direction. The limestones referred to in the Red Sea area changed from massive limestones (not oolitic, but to some extent dolomitic) on Jubal Island at the edge of the reef, to oolitic limestones interbanded with beds of very fine sediment on Gaysum Island, half-way between Jubal and the coast; while on the mainland, they consisted of oolitic limestones with many gasteropod-remains, interbedded with sands and coarse grits—very like the material of the Millstone Grit. The later oolites were evidently laid down in the estuary of some river.

He was interested to hear that Mr. Tiddeman had long considered that some of the oolites of Gower might have been laid down under æolian conditions, because some of the oolites in these recent Red-Sea beds were probably affected by similar conditions. It seemed, therefore, that the conditions which the Authors considered to have existed during the deposition of these beds in Gower, might find a close parallel in the conditions which recently existed, and probably still exist, in the northern part of the Red Sea.

Mr. DIXON, after thanking the Fellows for their kind reception of the paper, remarked, with reference to an observation by the President, on the usefulness of a classification of the Lower Carboniferous in facilitating comparison of developments in different districts; and added, in reply to Mr. Tiddeman, that the occasional occurrence of large marine fossils in even the most unfossiliferous oolite militated against the view that any of these rocks were of æolian origin.

Regarding the name to be applied to the shales above the Limestone Series in Gower, the Pendleside Series had good claims, in that it represented rocks to which a distinctive fauna had been ascribed; and further, in answer to an objection raised by Dr. Strahan, he remarked that the correlation depended not solely on the occurrence of *Posidonomya becheri* Bronn, but rather on that of *Glyphioceras spirale* Phill. In agreement with Mr. Tiddeman, he did not think that any of the Gower limestones possessed features characteristic of true coral-reefs.

In reply to Mr. Leach and others, he stated that the calcareous 'lagoon-phases'—the *Modiola* phases—were all distinguished in places by exceedingly fine-grained calcite-mudstones with an impoverished fauna of lamellibranchs (especially *Modiola*), ostracods, and *Spirorbis*.[1] A certain amount of terrigenous material, mud and fine sand, was found in them all.

He took exception to Dr. Sibly's remark that the Gower area had been exceptionally shallow; on the contrary, he considered it in many respects typical of the South-Western Province.

He was very glad to hear from Mr. Wade that the conditions which must have prevailed during lagoon-phases could be approximately paralleled at the present day along the coast of the Red Sea, as he had not had an opportunity of enquiring whether modern representatives of them were known. The suggestion of Mr. Cosmo Johns that a lowered sea-temperature might account for the absence of dolomite from the Upper Avonian of the North-Western district was welcomed, as the speaker had suspected that the influence of the waters that deposited the Pendleside Shales was beginning to make itself felt there at that time, and a low temperature would also explain the extermination of the previously-rich fauna from the area on the arrival of those waters in force.

In conclusion, he remarked that, although there appeared to be no reason why lagoon-conditions should not be established during any shallow-water period, it was a matter of observation that they immediately preceded sharp subsidence.

---

[1] Lack of time prevented the speaker from illustrating the differences between the lagoon-phase deposits and the standard limestones as being similar to those between the Rhætic—a typical lagoon-phase—and the open-sea Lias.

18. Contributions *to the* Geology *of* Cyrenaica. By Prof. J. W. Gregory *and others.* (Read March 8th, 1911.)

[Plates XLII–XLIX.]

(A) *The* Geology *of* Cyrenaica. By John Walter Gregory, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

[Plate XLII—Map and Sections.]

Contents.

I. Introduction.

Cyrenaica, a province of Eastern Tripoli, is the projection on the northern coast of Africa between the Gulf of Sidra (the Greater Syrtis) on the west and the Bay of Bomba on the east. The name is sometimes used to include Marmarica and the Libyan coast, as far as the still undetermined western frontier of Egypt; but the restriction of Cyrenaica to the wide foreland occupied by the famous Greek colony whose capital was Cyrene renders it a more natural geographical division. It is thus equivalent to the Gebel el Akdar—the Green Hills—of Arab nomenclature; while the Gebel el Akabah—the Abrupt Hills,—its eastward continuation between the Bay of Bomba and the Bay of Salum,[1] is the plateau of Marmarica.

Cyrenaica, as thus restricted, is a land of great classical interest: it includes the ancient Pentapolis; the city of Cyrene stood on the northern edge of its plateau; and the Garden of the Hesperides and the River Lethe lay in hollows in the limestone on its coastal plain.

---

[1] The spelling of most of the Egyptian place-names is adopted from the recent map of Egypt published by the Geological Survey of that country.

Cyrenaica is, however, geologically the least-known area on the shores of the Mediterranean. The geology of the parts of Egypt near the eastern frontier of Cyrenaica is known from the work of Zittel[1] and Fuchs[2] at Siwa, and from collections made on the coast of Marmarica at Mersa Tobruk by Schweinfurth,[3] and on the Libyan coast by Ball[4] and by Pachundaki[5] at Mersa Matruh, about half-way between Alexandria and the Bay of Salum. The correlation of the rocks on the eastern frontiers of Cyrenaica has been carefully discussed by Dr. Blanckenhorn.[6] An admirable summary of the geological data regarding Cyrenaica was published in 1904 by Dr. Hildebrand, who shows that the existing information was then both scanty and uncertain.[7]

From the evidence available in 1908, three different explanations of the geological structure of Cyrenaica were possible. It might be a fragment of a mountain-loop that had once connected the Atlas with the mountain-ranges of Crete and Asia Minor; or it might be a plateau of Eocene rocks—an outlier of the Mokattam Series of Egypt; or again, it might be a horst of Miocene and Pliocene limestones, once continuous with those of Malta.

The first theory—the connexion between Cyrenaica and the Atlas—was suggested by several considerations, including the probability that the mountains of Cyrenaica had an axial core of ancient rocks.

The first information as to the geological structure of Cyrenaica was collected by Della Cella, an Italian doctor who accompanied a military expedition led by the Bey of Tripoli into Cyrenaica in 1817. Della Cella clearly recognized that the mountains of Cyrenaica were not a simple continuation of the Atlas, though he regarded both areas as composed of similar rocks. He remarks:—

'In some of my letters, I have attempted to shew, that the mountains of the Cyrenaica form no part of the eastern prolongation of that chain which

---

[1] K. A. von Zittel, 'Beiträge zur Geologie & Paläontologie der Libyschen Wüste & der angrenzenden Gebiete von Ægypten' Palæontographica, vol. xxx, pt. 1 (1883) pp. cxxiv–cxxxvi.

[2] Th. Fuchs, 'Beiträge zur Kenntniss der Miocän-Fauna Ægyptens & der Libyschen Wüste' *Ibid.* pp. 18–66 & pls. vi–xxii.

[3] G. Schweinfurth, 'Ein Besuch in Tobruk an der Küste von Marmarica Marineverordnungsblatt, No. 47 (1883) pp. 14–29. For reference to the discovery of these fossils, see G. Hildebrand, 'Cyrenaïka als Gebiet künftiger Besiedelung' Bonn, 1904, pp. 78–79, and M. Blanckenhorn, 'Neues zur Geologie & Paläontologie Ægyptens, III. Das Miocän' Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) pp. 104–105.

[4] Maps of the Districts of Mersa Matru & Ras Allem Rum 'showing . . . and the Main Outlines of the Surface-Geology'—scale 1 : 25,000. Cairo, 1903.

[5] D. E. Pachundaki, 'Sur la Constitution Géologique des Environs de Mirsa Matrouh (Marmarique)' C. R. Acad. Sci. Paris, vol. cxxxvii (1903) pp. 350–51; also 'Contribution à l'Étude Géologique des Environs de Marsa Matrouh (Marmarique)' Revue Internationale d'Égypte, vol. iv (1907) 36 pp., pt. ii.

[6] M. Blanckenhorn, 'Neues zur Geologie & Paläontologie Ægyptens, II. Das Palæogen' Zeitschr. Deutsch. Geol. Gesellsch. vol. lii (1900) table facing p. 406; and 'III. Das Miocän' *ibid.* vol. liii (1901) table facing p. 52.

[7] G. Hildebrand, 'Cyrenaïka als Gebiet künftiger Besiedelung' Bonn, 1904, pp. 77–95.

> rises upon the northern border of the African coast, and extends from the western shores of the gulph of the Great Syrtis as far as the kingdom of Morocco; and my observations upon the termination of the gulph demonstrate that there exists no such connexion. But this does not prevent the calcareous constitution of Mount Atlas from forming also the character of the Cyrenean mountains. I am unacquainted with the Atlantic chain of mountains to the west of Tripoli, but I have seen several specimens of the rocks between Tripoli and Tunis, and they display the same character and formation.'[1]

He recorded the presence in Cyrenaica of many fossils different from the existing Mediterranean fauna, and he described some of the fossils from the mountains as 'presenting in their fractures the character of Ammonites.'[2] It therefore appeared possible, from Della Cella's statements, that Cyrenaica might have a foundation of Mesozoic rocks containing Ammonites.

The existence in Cyrenaica of Palæozoic or pre-Palæozoic crystalline marbles seemed also possible. For, according to Della Cella,

> 'the heart of these mountains consists of a compact chalk which has the usual hardness of all kinds of marble; and, though of secondary formation, and bearing frequent traces of shells, its grain is fine and often glitters like saline marble.' (*Op. cit.* p. 116.)

The Italian traveller Camperio remarked[3] in 1882, that the marble used for the statues at Cyrene might either have come from the Greek islands or from the neighbouring mountains. The statues, of which the British Museum has a valuable collection, are of saccharoidal marble, and so also is the one specimen that I have examined in the Louvre. Hence Capt. Camperio's suggestion of the local origin of this material was consistent with the occurrence of a Palæozoic, or perhaps even older, formation in the mountains of Cyrenaica.

Hamilton, in 1856, described the coast-hills from the Wadi Nagr, where the track to Cyrene leads on to the plateau, past Derna towards Ras el Tin, as composed of 'barren sandstone,'[4] and Dr. Hildebrand[5] quotes Meier-Jobst as asserting the occurrence of sandstone at Cyrene on the summit of the plateau. These reports suggested that sandstones might play an important part in the structure of Cyrenaica.

The geological evidence connecting the Cyrenaican mountains with the Atlas was indefinite; but it was supported by the con-

---

[1] Paolo Della Cella, 'Physician Attendant on the Bey': 'Narrative of an Expedition from Tripoli in Barbary to the Western Frontier of Egypt, in 1817, by the Bey of Tripoli; in letters to Dr. Viviani of Genoa, by . . .; with an Appendix, containing instructions for navigating the great Syrtis.' Translated from the Italian by Anthony Aufrere, Esq. London, 1822, pp. 165–66.

[2] *Ibid.* p. 165. The original of this passage is as follows:—'Talvolta trovasi guarnita di piccoli testacei lentiformi, che nella loro spaccatura presentano i caratteri delle Ammoniti' (Lettera xiii, p. 162).

[3] Camperio, 'Una Gita in Cirenaica' Esploratore, vol. vi, 1882, p. 16.

[4] James Hamilton, 'Wanderings in North Africa' 1856, p. 113.

[5] G. Hildebrand, 'Cyrenaïka als Gebiet künftiger Besiedelung' Bonn, 1904, p. 86.

clusions of Sir R. Lambert Playfair, who, in his Presidential Address to the Geographical Section of the British Association in 1890, accepted Cyrenaica (from geographical considerations) as a detached fragment of the Atlas Mountains.

> 'The Atlas range'..., he states, 'runs ... through Algeria and Tunisia; it becomes interrupted in Tripoli, and it ends in the beautiful green hills of the Cyrenaica, which must not be confounded with the oases of the Sahara, but is an island detached from the eastern spurs of the Atlas, in the ocean of the desert.' ('The Mediterranean, Physical & Historical' p. 875.)

This view, however, has not received any recent support,[1] and Cyrenaica has been generally regarded as a plateau of Kainozoic rocks. Thus Taramelli & Bellio, on their geological map of Africa,[2] represent Cyrenaica as composed wholly of Eocene and Oligocene formations; they refer to the country as having been separated from the older rocks of the Sahara by a Pleistocene sea, some of the evidence for which they regard, however, as doubtful.

The occurrence of Eocene rocks in Cyrenaica appeared probable from the identification of nummulites in them. Thus, the Archduke Salvator[3] described the walls of the Cave of Lethe as composed of 'Nummulitenkalk.' Dr. Hildebrand[4] quotes a statement by Haimann ('Cirenaica' 1886) that the mountains of Cyrenaica are formed of an Eocene limestone full of nummulites. Hildebrand nevertheless rejected the reported nummulites and Eocene beds as based on unerliable evidence[5]; and, in regard to the rock at the 'River' Lethe, his scepticism was justified, for it contains *Orbitoides* and not nummulites. He expressed himself in doubt whether the sandstones reported along the coast of Cyrenaica are the outcrop of an Eocene base of the country, or whether, as he thought more probable, they are a Pliocene or 'Quaternary' series deposited upon the flanks of the Miocene limestone (*op. cit.* p. 86). Hildebrand was quite correct in his view as to the recent age of the low-level sandstones; but, despite his remarkably thorough acquaintance

---

[1] It is, however, consistent with some recent topographical maps, as, for example, C. Diercke, 'Europa. Bodenverhältnisse' Schulwandkarten, 1:3,000,000, Brunswick.

[2] T. Taramelli & V. Bellio, 'Geografia & Geologia dell' Africa' Milan, 1890, pl. ii.

[3] [Ludwig-Salvator] 'Yacht-Reise in den Syrten, 1873' Prag, 1874, p. 52. Reprinted as 'Eine Yachtreise an den Küsten von Tripolitanien & Tunisien.' Woerl's Reisebibliothek, Würzburg, 1890, p. 49.

[4] G. Hildebrand, 'Cyrenaïka als Gebiet künftiger Besiedelung' Bonn, 1904, p. 83.

[5] 'These two records'—those of Haimann and the Archduke—'are therefore for us especially important,' says Hildebrand ('Cyrenaïka' 1904, pp. 83–84), 'because they are in direct opposition to all others that we know. For there is scarcely any mention of nummulites, which would certainly point to an old Tertiary formation, and still less of formations of the Eocene time. These statements as to age stand quite alone. Besides, they inspire no special confidence. Haimann was neither geographer nor geologist, as may be recognized "Schritt und Tritt." And the Archduke Salvator also makes no claim to geological knowledge.'

with the literature of Cyrenaica, he overlooked Admiral Spratt's account of the geology of Derna and the identification of a nummulite from Mersa Susa by the late Prof. T. Rupert Jones.

The most precise geological information regarding Cyrenaica was given by Admiral Spratt[1]; but, as it was an Appendix to a book on Crete, it has been overlooked. He contrasted the jagged mountains of Crete with the plateaux of Libya extending from Tripoli to the Nile; and he recognized the numerous sudden flexures of the coast, as in the Syrtis, the Gulf of Salum, and at Ras el Tin, as due to faults. His most important contribution to the geology of Cyrenaica was an account of the section at Derna, which he described as composed of a lower series of white or cream-coloured limestones 'full of nummulitic shells resembling those of Crete' (*op. cit.* p. 377); and this lower series, 250 feet thick, he described as passing conformably upwards into yellowish marly sands or sandstone, resembling the yellow sandstones of Malta and containing many of the Maltese fossils. That Spratt's foraminifera were really nummulites cannot be doubted, as one specimen, now in the (Natural History) British Museum, was identified as the Lower Eocene *Nummulites perforata*.[2]

The identification of nummulites from Cyrenaica having been overlooked or discredited, Cyrenaica has been generally described in recent years as composed of a sheet of Miocene and perhaps also Pliocene limestones. This view was expressed by Dr. Gürich,[3] who described the country as mainly Middle Miocene; and he appears to exclude the possible occurrence of Oligocene deposits by reference to the existence of an important gap in this region between the Eocene and the Miocene. Zittel[4] and Suess[5] both also accepted Cyrenaica as Miocene. Suess referred to it, though doubtfully, as belonging to the second Mediterranean stage—that is, Upper or Middle Miocene. This view was based on the collections made by Schweinfurth at Mersa Tobruk, on the coast of Marmarica; and in Suess's sketch-map (*loc. cit.* fig. 41) the whole country is represented as belonging to the Upper Mediterranean stage and younger formations, while the later French edition by M. de Margerie[6] includes a map after G. Rolland, in which the country is all marked as Middle Miocene. According to the last statement on the subject, issued in 1907 by M. D. E. Pachundaki,[7] the

---

[1] T. A. B. Spratt, 'Travels & Researches in Crete' vol. ii (1865) app. iv, pp. 375–80.

[2] T. R. Jones, 'Catalogue of the Fossil Foraminifera in the British Museum (Nat. Hist.)' 1882, p. 45.

[3] G. Gürich, 'Ueberblick über den geologischen Bau des afrikanischen Kontinents' Petermann's Mitteilungen, vol. xxxiii (1887) p. 261 & pl. xiii..

[4] K. A. von Zittel, 'Beiträge zur Geologie & Paläontologie der Libyschen Wüste' Palæontographica, vol. xxx (1883) pp. xxvi–xxvii & cxxxi.

[5] E. Suess, 'Das Antlitz der Erde' vol. i (1885) p. 465.

[6] 'La Face de la Terre' vol. i (1897) pp. 459 (fig. 68) & 464.

[7] D. E. Pachundaki, 'Contribution à l'Étude Géologique des Environs de Marsa Matrouh (Marmarique)' Revue Internationale d'Égypte, vol. iv (1907) p. 8.

conclusion of Zittel as to the age of the 'Plateau Marmarico-Cyrenaïque' had been confirmed.

With such an array of authority in favour of the Miocene age of the rocks, it is not surprising that the 'Carte Géologique Internationale de l'Europe' (Sheet D vii), issued in 1905, colours the whole of Cyrenaica as Miocene, except for a band of recent formations along the coast and in some of the wadis, and a strip of 'Quaternary' running inland from Benghazi to the Wadi el Bal, as also an area of the same age beside the Gulf of Bomba.

The scantiness of available information as to the geology of Cyrenaica is due to the country having been closed to travellers, especially during recent years, by the Turkish authorities. Most of those who have visited Cyrenaica have been archæologists, whose attention has been engaged by its numerous antiquities, or Italian explorers interested in its commercial resources and its suitability for Italian colonization.

In 1908 I had the opportunity of visiting Cyrenaica as leader of an expedition sent to investigate whether the country would be suitable as a colony for Jewish refugees.[1] In spite of the support and the firman of the late Redjeb Pasha, then the enlightened Governor of Tripoli, the conditions were not always favourable to geological survey. Moreover, as we landed at Derna on July 24th, 1908, and arrived at Benghazi on August 14th, after a march, including excursions off our main route, of about 300 miles, the geological study of the country was only in the nature of a rapid reconnaissance. I should have liked to go eastwards in the direction of the Egyptian frontier, to trace the connexion between the rocks of Cyrenaica and the Miocene limestones of Western Egypt and Marmarica; but I had pledged my word to Redjeb Pasha that we would not go farther east than could be managed in one day's journey from Derna.

After engaging a camel-caravan at Derna, and having been supplied with an escort by the officer in command of the Turkish garrison, we marched overland across the plateau of Cyrenaica to Benghazi on the Great Syrtis; we supplemented this traverse by excursions northwards to the coast and southwards to the open plains, as far as was allowed by time, water-supply, and the Turkish permission.

I have to express my great indebtedness for the opportunity of the journey across Cyrenaica to Mr. Israel Zangwill, who arranged the expedition and secured the consent of the Turkish authorities; also to my companions Mr. M. B. Duff, Dr. M. D. Eder, Dr. J. Trotter, and Prof. M. N. Slousch, for the pleasure of their company

---

[1] J. W. Gregory, 'Report on the Work of the Commission sent out by the Jewish Territorial Organization under the Auspices of the Governor-General of Tripoli to Examine the Territory proposed for the Purpose of a Jewish Settlement in Cyrenaica.' The report includes an Introduction by Israel Zangwill; an Agricultural Report by J. Trotter; a Report on the Water-Supply and Engineering by R. E. Middleton, W. Hunter, & M. B. Duff; a Medical Report by M. D. Eder; and an Appendix by Prof. N. Slousch, 52 pp., 3 maps, 14 pls. London, 1909.

and the benefit of their indefatigable co-operation. They collected many of the fossils, and to Mr. Duff is due the map of our route,[1] on which the geological map (Pl. XLII, fig. 1) is based. I have also to express my thanks to Mr. Justin C. W. Alvarez, our Consul-General at Tripoli, and to Messrs. R. A. Fontana and G. Farrugia, the British Consuls at Benghazi and Derna, and to M. Jacoub Krieger, the confidential secretary to the late Redjeb Pasha, for his unfailing courtesy and help.

I am greatly indebted to Mr. R. B. Newton for the care with which he has studied the fossil mollusca collected by the expedition, and the accompanying memoir on them. I am also indebted to Mr. F. Chapman for his report on the foraminifera, and to Mr. D. P. Macdonald for his careful microscopic examination of the limestones. Dr. C. W. Andrews has kindly helped me with reference to the literature on the fossil mammalia of the adjacent areas.

The magnetic variation in Cyrenaica was taken as 6° W.

For the literature on Cyrenaica, reference may be made to two chief bibliographies—R. L. Playfair, 'The Bibliography of the Barbary States: Part I, Tripoli & the Cyrenaica' Roy. Geogr. Soc., Supplementary Papers, vol. ii, pt. 4 (1889) pp. 559–614; and G. Hildebrand, 'Cyrenaïka als Gebiet künftiger Besiedelung' Bonn, 1904, pp. 329–78.

II. Field-Observations.

(*a*) The Neighbourhood of Derna.

Derna is situated on a delta-fan of limestone-gravel at the mouth of the Wadi Derna. The gardens in the town are irrigated by water from springs at Seghia and Bonmansur, respectively about 4 and 5½ miles up the wadi. The river-bed is covered by coarse limestone-shingle, and is usually waterless. It forms, in fact, the main thoroughfare through the town. Above Derna the river emerges from a deep gorge, and near its mouth is a bank of tufa, which rises to the height of 100 feet up the eastern side of the wadi: it consists of successive layers of calcareous sand, of tufa largely composed of cylindrical fragments, and of rolled limestone boulders. This deposit obviously represented a delta-fan which had been formed at the mouth of the wadi, before the gorge had been corroded to its base-level. The material was due to the alternate deposition of coarse shingle during floods, and of tufa during intervals when the only water came from adjacent springs.

The sections along the Wadi Derna expose two main rocks: the lower part of the cliffs consists of a soft white to cream-coloured limestone, crowded with large flat nummulites, and similar to the typical Nummulitic Limestones of the Mokattam Series of Egypt.

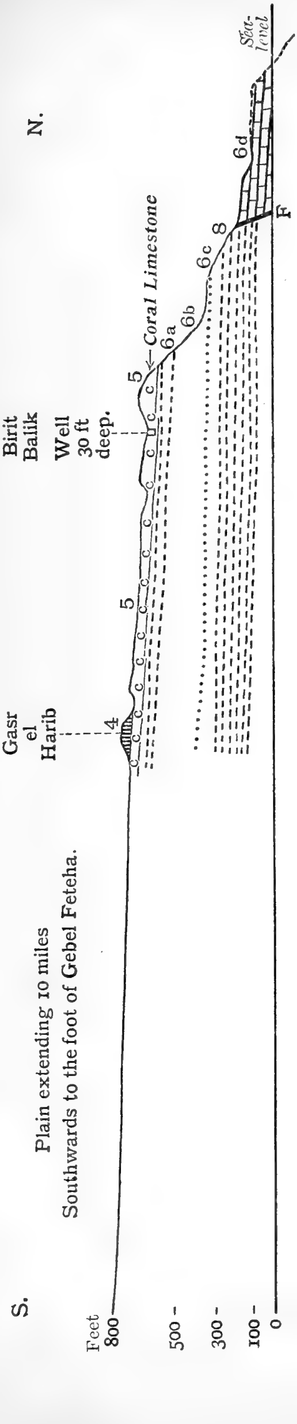
According to Mr. Chapman, the foraminifera, which are unusually well preserved, are of Middle Eocene age. The most characteristic

---

[1] [A MS. copy of the map will be placed in the Society's Library.]

Fig. 1.—*Section drawn southwards from a point about 6 miles south-east of Derna; approximate length = $6\frac{3}{4}$ miles.*

[Horizontal scale: 1 inch = 1 mile.]



4 = Limestone with *Schizaster ederi* (Aquitanian).

Upper Eocene (Slonta Limestones).
5 = Massive coral-limestone.
6*b* = Nummulitic limestone.
6*a* = Sandy nodular limestone.
6*c* = Friable limestone with *Operculina lybica* and *Nummulites curvispira.*
6*d* = *Pecten-arcuatus* Limestone.

8 = Derna Limestones (Middle Eocene).

species is *Nummulites (Paronia) curvispira* Menegh.[1] Old rock-dwellings have been excavated in this rock, which extends up the wadi as far as we could see. It includes layers of broken shell-fragments and echinoid spines, and some layers, as at Seghia, of pinkish limestone full of *N. curvispira* and *N. ehrenbergi*, 2 inches in diameter. This cream-coloured limestone and its associated beds, which may be grouped together as the Derna Limestone, are some 250 feet thick. This series is covered by harder limestones, which weather brown and are more conspicuously stratified. They are over 200 feet thick at Derna, and from their great development at Slonta are subsequently referred to as the Slonta Limestones.

About 6 miles from Derna the wadi divides at the springs of Bonmansur; a platform composed of 20 feet of calcareous sands and gravels, interbedded with layers of travertine from 1 to 3 feet thick, separates the two branches of the valley. The face of this platform is covered by a sheet of calcareous tufa with many fantastic projections. The sands contain shells, which have been identified by Mr. R. B. Newton as *Hygromia sordulenta* (Morelet), showing the age to be

---

[1] In the following pages any foraminifera the species of which are mentioned have been determined by Mr. Chapman, and similarly the mollusca by Mr. R. B. Newton.

Pleistocene. The surface of the platform is strewn with so many palæolithic chert-implements, that it was probably the site of an ancient camp.

The stratigraphical relations of the Derna Limestone are shown by a section across the face of the plateau, about 5 miles south-east of the town, from an ancient megalithic ruin known as Gasr el Harib to the wells at Bint. The ruin stands at the height of 750 feet near the northern edge of the plateau, which extends far southwards, to the foot of the hills of Gebel Feteha. The northern face of the plateau shows a good section, illustrated by fig. 1 (p. 579). The lower part of the main scarp, up to the height of about 200 feet above sea-level, consists of the cream-coloured Derna Limestone: this is overlain, at the height of 340 feet above sea-level, by a sandy foraminiferal limestone, from which Mr. Chapman has identified fourteen species of foraminifera, including *Nummulites curvispira* and *Operculina libyca.*

Above this foraminiferal bed follow 60 feet of the brown-weathering, well-bedded limestones; they end above in a hard rock containing reef-building corals. This coral limestone forms a shoulder on the scarp, surmounted by a megalithic ruin. Above this point there is a more gradual ascent on to the plateau, up a valley cut through a series of massive rough-weathering limestones, and having on its floor some ancient wells from 30 to 40 feet deep, still used by the Arabs. Upon the plateau are some hills of a soft, marly, friable limestone of a pale buff colour, resembling some layers of the *Globigerina* Limestone of Malta; it yielded a *Schizaster* which, although too crushed for certain specific determination, resembles *Schizaster ederi*, sp. nov.

The main sequence in this section is, therefore, from a limestone which is probably Aquitanian, through the Slonta Limestones, down to the Derna Limestones. At the foot of the main scarp is a belt of limestones, one of which, at 200 feet above sea-level, yielded a fossil determined by Mr. Newton as the Priabonian *Pecten arcuatus* Brocchi, and consequently belonging to a horizon much higher than the rocks level with it in the cliffs on the south. The steep scarp south-east of Derna is, therefore, probably a fault-scarp, and the foot-hills at the coast are composed of the downthrown Slonta Limestones. I had, however, no opportunity of collecting further specimens from this area, or of completing the section to the sea.

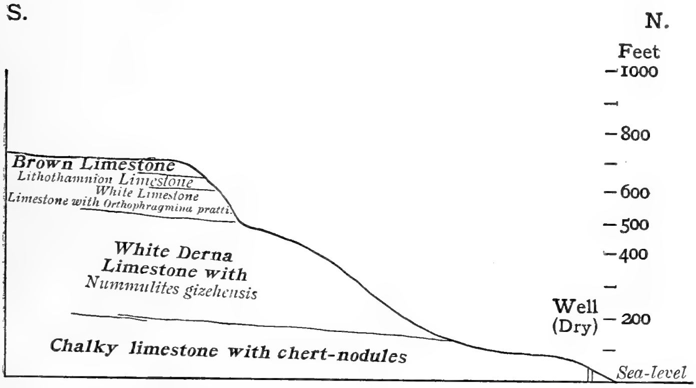
(*b*) Derna to Cyrene.

We marched from Derna for about 6 miles westwards along the coast, crossing a belt of shore-deposits and delta-fans, which sloped up from the sea to the foot of the plateau-scarp. Along the lower part of the cliff could be seen the cream-coloured Derna Limestones, capped by the bedded, brown-weathering limestones. In a wadi about 3 miles west of Derna, the limestones on the coastal plain dip 5° northwards. Outcrops of a chalky limestone containing flint nodules occur to the west of a wadi, about 4 miles from Derna, and

form a small hill between the path and the shore. This chert-bearing rock is also well exposed in the banks of the Wadi Nagr, where it is represented by a soft chalk-like limestone with lines of flat chert-nodules, dipping 5° northwards. This chert-bearing limestone extends along the foot of the cliffs, to the west of our camp.

West of the wadi, Dr. Trotter collected a fossil which Mr. Newton has determined as *Lucina* cf. *nokbahensis* Oppenh., in a limestone free from *Nummulites*. If this specimen were *in situ*, then, as at Bint, east of Derna, Upper Eocene rocks are faulted down at the foot of the plateau-scarp.

Fig. 2.—*Section in the plateau-face at Wadi Nagr, west of Derna.*



The sequence of the rocks in this district may be observed in the ascent of the Okbah or Aukubah, the Arab name for the cliff which forms the northern face of the plateau. The rocks are well exposed there, except that some bands are covered by an efflorescent limestone-crust. The chalky chert-bearing limestone passes gradually up into a harder limestone with chert-nodules, which is succeeded by the cream-coloured *N.-curvispira* Limestone: this, being very soft, has been carved into caves, and is in places overhung by the rock above. At about 500 feet above sea-level the slope becomes steeper, up a cliff of the brown-weathering limestones (the Slonta Limestones), which begin with a layer of limestone full of small foraminifera, succeeded by a white limestone with *Orthophragmina pratti* and *Operculina*, which continues up to the height of about 630 feet. It is succeeded by a pinkish limestone, 30 feet thick, containing nullipores and some foraminifera, among which Mr. Chapman has identified *Nummulites curvispira* and *Truncatulina*; so he refers the brown limestones to the Middle Eocene. At 660 feet is a band of white marl, followed by the typical brown-weathering limestone, which continues to the edge of the plateau at about 750 feet. (See fig. 2, above.)

From the edge of the plateau above the Wadi Nagr the country rises gradually westwards and southwards, although the surface is broken by deep wadis. The Slonta Limestones, containing occasional shelly horizons, form the surface of the plateau. The dip is slight and to the north. A limestone with casts of reef-building corals occurs at the height of a little over 1100 feet, about 7 miles west of our first camp. A short distance farther west we saw exposures of a soft yellowish limestone, which we had the best opportunities of examining in the wells near an Arab burial-ground known as Birlibah. Here I found an echinoid, *Hypsoclypeus hemisphericus* (Greg.), the first Miocene[1] fossil found.

From Birlibah to Gubah, a distance of about 12 miles, the country is thinly wooded moorland. It rises gradually from 1100 to 1800 feet; the rocks are yellowish granular limestones, with some nodular, marly seams, which, especially near Wadi Umzigga, form a number of small springs. The characteristic fossil is a large pecten, which Mr. R. B. Newton has identified as *Oopecten rotundatus* (Lam.). The fossil mollusca collected at the Wadi Umzigga and seen at other adjacent exposures, indicate that these limestones are not lower than Aquitanian; and, according to Mr. Chapman, the limestone at Wadi Umzigga is full of *Lepidocyclina elephantina* Mun.-Ch., and is Aquitanian or Stampian. The age of the Wadi-Umzigga beds may, therefore, be regarded as Aquitanian.

At Gubah, beside the ruins of a Greek bath, we found some fossils, among which Mr. Newton identified *Strombus coronatus* Defr., *Alectryonia plicatula* (Gmel.), and the cirriped *Balanus concavus* Bronn. He therefore assigns the rock to the Upper or Middle Miocene. After leaving Gubah, we ascended another platform about 100 feet high, formed of a rough-weathering limestone; but, as we were passing close beside a Senussi settlement, Zawiah Charrah, we had no opportunity of collecting fossils until 6 miles from Gubah, when we reached the ruins of the Roman town of Lamludeh (the ancient Lebdis). There we found some casts of lamellibranchs and a large gastropod, weathered out of beds of earthy limestone and marl: these fossils, according to Mr. Newton, indicate an Aquitanian age. West of Lamludeh the ground is rocky, and much of it is covered with scrub growing in the depressions between hummocks of a hard, white limestone, containing many large Ostreids, including *Ostrea crassicostata* Sow. Immediately west of Zawiah Turt is an exposure of a limestone containing many echinoid plates and foraminifera, and an associated limestone yielded an *Amphiope*.

At Labruk, 10 miles west of Lamludeh, the earthy limestones, like those at Lamludeh, crop out north of the track; close beside the water-hole is a band of hard limestone containing casts of reef-building corals. About half a mile west of Labruk is a bed containing many specimens of *Echinolampas*.

A waste of rocky scrub and rough hills of coral-limestone, with the *Echinolampas* Bed cropping out in the depressions, extends for 6 miles from Labruk to the marabut or shrine of Sidi Dia-

---

[1] For the accepted limit of the Miocene, see p. 593.

siasia (or Sidi Jaja). From our camp there we visited Safsaf, some bare limestone-hills used by the Romans as a collecting-ground for water, which was carried by an aqueduct to the city of Cyrene, 6 or 7 miles distant in a direct line. The same hard Slonta Limestones, which weather irregularly, occur north-west of Sidi Rof Diasiasia; they pass in that direction under a series of soft, earthy, white and grey limestones and marls. These rocks form the hills over which are scattered the widespread ruins of the city of Cyrene. The rocks agree lithologically with those of Lamludeh and the fossils collected show that the Cyrene Limestones are of Aquitanian age.

(*c*) Mersa Susa (Apollonia) to Slonta.

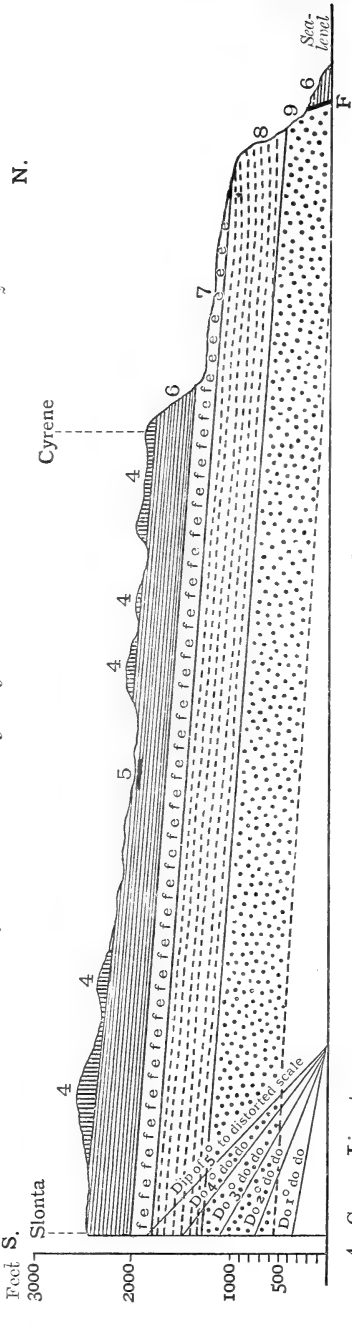
It was necessary for our work to determine the conditions which control the water-supply of the district near Cyrene and the chances of finding situations suitable for storage-reservoirs. Hence we made a north-and-south traverse across the country from the sea at Mersa Susa (Apollonia) through Cyrene, to the southern downs at Slonta. This section (fig. 3, p. 584) illustrates the general geological structure of that part of Cyrenaica.

The city of Cyrene stands at the height of about 1950 feet above sea-level, on the northern edge of a plateau which rises gradually southwards to 2700 feet near Slonta. Immediately north of Cyrene is a steep cliff, which falls to the level of about 1300 feet, whence a platform, generally referred to as the 'lower plateau,' extends for about 3 miles northwards, and from its edge, at the height of about 1000 feet, the steep lower cliff falls abruptly to the shore. The lower cliff, being the extension of the cliff near Mersa Susa, may be a fault-scarp; it was, therefore, necessary to consider whether the upper cliff at Cyrene was of the same origin. This view appeared the more possible, as a little below the Fountain of Apollo is a white soft limestone, containing nummulites indistinguishable in the field from those in the similar rock of the Derna Limestone, which is exposed in the upper part of the lower cliff. I could, however, find no repetition of the Echinoid Limestone, which overlies the Derna Limestone, above the upper nummulitic limestone, and was accordingly forced to reject the possibility of the two similar nummulitic limestones being the same bed repeated by faults. This conclusion is supported by Mr. Chapman's identification of the characteristic foraminifer of the upper limestone as *Nummulites gizehensis* var. *lyelli*; while that found in the Derna Limestone is the typical form of the species. The upper cliff, moreover, has the characters of an escarpment, and not of a fault-scarp: it has been cut back into numerous gullies, and projects between them in irregular spurs. The uneven escarpment-like weathering of the cliff is well shown in the plan of Cyrene by Smith & Porcher.[1]

---

[1] R. M. Smith & E. A. Porcher, 'History of the Recent Discoveries at Cyrene' 1864, pl. xl.

Fig. 3.—*Section from Slonta through Cyrene to the sea: distance = about $27\frac{1}{2}$ miles.*



4 = Cyrene Limestones.
5 = Reef-limestone at Wadi Firjah.
6 = Slonta Limestones, with *Nummulites gizehensis*, var. *lyelli*.
7 = *Filularia* and Echinoid Limestones.
8 = Derna Limestones, with *Nummulites gizehensis typica*.
9 = Apollonia Limestones.

The series is, therefore, a steadily ascending one from Mersa Susa to Cyrene.

The old port of Mersa Susa is built on a series of dune-limestones, behind which is an alluvial delta deposited by the Wadi Susa. The route to Cyrene goes westwards across the alluvial deposits for about a mile; and then, in the banks of a large wadi, limestone is exposed dipping 5° northwards and containing *Gisortia gigantea* Munst., *Trachycardium* cf. *granconense* Oppenh., and *Pecten arcuatus* Brocchi. Mr. Newton, therefore, refers this limestone to the Priabonian.[1] At the foot of the plateau the cherty limestones—the Apollonia Limestones—are exposed, and they continue up the track from 150 to 530 feet above sea-level. This limestone, as a rule, is massive, and contains many foraminifera and some shell-fragments. Some indeterminable molluscs were collected at the height of 450 feet in a band of cherty limestone. The chert-bearing series ends at the height of 530 feet with a chert-breccia. Above this follows the compact, creamy-white Derna Limestone, full of *Nummulites curvispira* and identical in character with that so well exposed at Derna. At 600 feet is a white, foraminiferal limestone with echinoid fragments. At 620 feet is an oolitic band, also observed at a corresponding position in the section above Ptolemeta.

---

[1] The specimen determined as *Nummulites perforata* by the late Prof. T. Rupert Jones from Mersa Susa doubtless came from the same limestone, with which it agrees lithologically. Mr. Newton has kindly examined it, and is disposed to regard it as *N. intermedia*, an Upper Eocene species.

The limestone at the level of about 900 feet is soft, and has been excavated for cave-dwellings. It passes, apparently gradually, into the hard, brown-weathering limestones; they form the surface of a wide plateau, which rises slowly inland to the foot of the upper or Cyrene Escarpment. At the level of 1100 feet, in the lower part of these limestones, is a layer crowded with scattered echinoid-plates.

This lower plateau has a rough, irregular surface with many limestone-hummocks, and small patches of thin soil in the hollows between them. This limestone continues past Ain Hafra, where it yielded the Priabonian *Euspira possaguensis* Oppenh., and forms the surface of the 'lower plateau' directly to the north of Cyrene. The section there begins on the north with the Echinoid Limestone at the height of about 1100 feet; it underlies a white hard limestone, which weathers very irregularly and forms the foundation of the plain covered by sandy alluvium north of Cyrene. At the base of the cliff which leads to the upper plateau is a limestone containing the Middle Eocene echinoid *Fibularia luciani* and *Nummulites curvispira*; it crops out at the height of 1215 feet. This rock is succeeded by a shelly limestone containing many nummulites, including *N. gizehensis* var. *lyelli*. The upper part of this '*lyelli*' limestone yields a few specimens of *Echinolampas*, one of which was collected from the height of 1320 feet; and the tombs of the northern necropolis of Cyrenaica have been mostly excavated in the beds of this soft foraminiferal limestone, which are interstratified with the harder bands.

The limestones used for the tombs are succeeded by a marly limestone, which is full of irregular nodules and many flattened stem-like fragments, and contains grains of glauconite. This bed has an irregular horizontal lamination, which helps to render it relatively impermeable to water sinking downwards through the overlying porous jointed limestone. This layer accordingly throws out a series of springs along the face of the escarpment. The most famous is the 'Fountain of Apollo' (or Ain Sciahat), at the height of about 1760 feet above sea-level. The limestone above the Fountain of Apollo is massive and contains some reef-corals, and it passes into a soft earthy limestone containing layers of marl and many pectens, identified by Mr. Newton as *Æquipecten zitteli* Fuchs, *Æ. camaretensis* (Font.), *Æ. scabrellus* (Lam.), *Pecten vezzanensis* Oppenh., etc.: the horizon is, therefore, Aquitanian. This *Pecten* Bed and the limestone above it also yielded some echinoids, including one which, though imperfect by reason of weathering, I had no hesitation in identifying from its characteristic form as *Hemiaster scillæ*. According to this identification, the echinoids agree with the mollusca in demonstrating the Aquitanian age of the Cyrene Limestones.

The general dip of the rocks in this area is slightly northwards, but occasionally it is reversed, and in the hill-face east of Ain Sciahat is a clear dip of 3° southwards.

The hills south of Ain Sciahat, between it and the upper part of the wadi of Bil Ghadir, the next wadi to the west, consist of the Cyrene Limestones, with the spring-forming marl at their

base. The upper part of that wadi is a deep ravine, cut by the recession of a waterfall which exists only in the rainy season. Above the fall the valley continues as a wide dale, on the floor of which are exposures of the limestone that overlies the nodular seam of the Fountain of Apollo. The Cyrene Limestones extend for about 2 miles to the south, and then, after crossing a flat-floored valley covered with a sheet of alluvium about a mile in length, the ground rises to scrub-covered hills of the hard Slonta Limestones. The *Echinolampas* Bed occurs at a well known as Bir-Hu, at the height of 2020 feet. The country is intersected by a series of deep ravines, and water must be more easily obtained here than in most parts of Cyrenaica. About a mile south of Bir-Hu is a ridge capped by the Cyrene Limestones, and on the lower ground to the south the rough-weathering hummocky limestone containing casts of shells and *Echinolampas* crops out at Gaafs-a-mudi. At the height of 2200 feet in the Wadi Firyah, above the horizon of the *Echinolampas* Bed, is a limestone full of reef-building corals. A little farther south, at the height of 2470 feet, we crossed the divide between those streams the beds of which descend northwards through the Wadi Firyah and those that begin their course southwards in the direction of Slonta. At the height of 2350 feet is a well, in which the water is upheld by a laminated sandy limestone containing flattened stems like that at Ain Sciahat. It yields many shell-fragments. The limestone above it yields the same pectens as at Ain Sciahat, and also *Ostrea crassicostata* G. B. Sow.; it is evident, therefore, that the beds are of Aquitanian age.

This outlier of the Cyrene Limestones is about 3 miles wide, and it is succeeded on the south by the nummulitic Slonta Limestones, which are much harder and weather brown. They contain, as below Ain Sciahat, *N. gizehensis* var. *lyelli*, and many specimens of *N. curvispira*, the latter of which, however, occurs also in the Derna Limestones. I did not see the coral-limestones which usually mark the upper bed of the Slonta Series, probably owing to the enforced quickness of our march. The Slonta Limestones here form open treeless downs extending as far southwards as we could see. The *Echinolampas* Bed occurs on the summit of some of the hills near a conspicuous landmark, the shrine of Sidi Mahomet Mahridi, as also at the old Roman cisterns near Slonta.

A few Arabs were living at Slonta, and I endeavoured from them to learn the nature of the country farther south. North of the shrine of Sidi Mahomet Mahridi we had crossed a slight ridge at the height of 2600 feet above sea-level; the well at Slonta is at 2400 feet, and the country apparently has a long gradual slope southwards. According to the sketch-maps of this district, the Cyrenaican plateau descends to the Siwa-Aujela depression in two abrupt steps. But, according to the Arabs, the plateau sinks gradually into the plains to the south.

(*d*) Slonta to Messa.

From Slonta we marched northwards up a picturesque dale cut through well-stratified limestones, which are either horizontal or have a dip of about 1° to the north. The rocks included a bed yielding *Echinolampas*, bands with small nummulites, and some containing a large nummulite 2 inches in diameter. We camped beside a Roman fort at Shermatu, and thence descended into the deep ravine of the Wadi Khumas near its head. This wadi descends to the north: its cliffs at first consist of the brown-weathering stratified Slonta Limestones; but farther north the cream-coloured Derna Limestones, presenting the same characters as at Derna and south of Mersa Susa, appear from beneath the upper series. The Derna Limestone cropped out from the level of 1860 feet in the upper Wadi Khumas down to 1240 feet. As the top of this formation near Mersa Susa, 18 miles away to the north-east, is at 1000 feet above sea-level, the dip of the rocks in this part of Cyrenaica must be 1° downwards to the north-east.

We descended the Wadi Khumas for 4 miles and left it where, at the level of 1240 feet, it turned westwards; we rode up a tributary gully on to the Messa plateau. The top of the cream-coloured Derna Limestone in this gully is at a little over 1300 feet, and the brown stratified Slonta Limestones, containing mollusca identified by Mr. Newton as *Lucina* cf. *pharaonis* Bellardi, *Mactra* cf. *fourtaui* Cossm., and *Cardita* cf. *acuticostata* (Lam.), extended from that level to the summit at 1640 feet. Our path joined the main track from Cyrene to Messa near a well, at the height of 1520 feet, in a stratified limestone which contains some clay and flattened stems, and thus resembles the impermeable layer of the Fountain of Apollo. The adjacent limestones yielded *Echinolampas chericherensis*, a species characteristic of the upper part of the Slonta Series. Thence we crossed a rough limestone-ridge and descended to Messa, where there are several springs produced by the laminar limestone with stem-like fragments. Owing to lack of time, I was unfortunately unable to continue the section from Slonta through Messa to the coast.

(*e*) Messa to Merj.

At Messa we joined the track from Cyrene to Benghazi. The wells at Messa are among the most important in Cyrenaica. They lie on the floor of a deep valley, and are maintained by drainage from the limestone around. The supply seems to be unfailing, and is sufficient for the irrigation of some gardens. The adjacent ruins show that the wells were important in ancient times. On leaving Messa we climbed on to the plateau, and crossed for 3 miles scrub-covered limestone moors to the shrine of Abdul Wahil. Thence we descended a steep path into a tributary of the Wadi Jeraib (or Wadi Ishgerib, or Jerib), and we followed the tributary until it joined the main valley. The cliffs of the Wadi Jeraib are in

places almost vertical, and they consist in part of the cream-coloured Derna Limestone. Farther down the wadi the cliffs increase to the height of about 400 feet, and the Derna Limestone is doubtless capped by the Echinoid Limestone, as fallen blocks of this rock lay at the foot of the cliff. We descended the Wadi Jeraib to the level of about 820 feet, when it bent round to the north-east.[1] There was no sign, even in the lowest part of the wadi, of the chert-bearing limestones. Leaving the main valley, we ascended a tributary to the south-west; we crossed the Echinoid Limestone above the Derna Limestone, and reached the surface of the plateau in front of the Roman castle, Gasr el Migdum. A limestone composed of reef-building corals crops out beside it, and on the west of it is a limestone containing small quartz-pebbles. The rocks in this area and for some distance westwards include more mechanically derived sediment than those farther east, and the ground is often covered by a white residual clay. From Gasr el Migdum we marched for 30 miles over an undulating limestone-plateau; the original surface varied in level from 1400 to 1500 feet, but it has now been dissected, by the excavation of numerous valleys, the floors of which are at the level of 1200 or sometimes of 1100 feet. The country is a wilderness of scrub, which became denser as we approached the Wadi Gharib.[2] The few fossils found included a large gastropod from below the shrine of Sidi Abdullah, identified by Mr. R. B. Newton as *Hippochrenes ampla* (Sol.), which we also found on the plateau south-east of Messa. This fossil and an occasional *Echinolampas* show that the rocks are of Upper Eocene (Priabonian) age. The last *Echinolampas* was found 6 miles east of the Wadi Gharib; but, as in that district we were marching in single file through dense scrub, we could not make any effective search for fossils. The valley of the Wadi Gharib shows fine sections of stratified foraminiferal limestones, resembling those of the Slonta Series. The rock-exposures, however, were covered with a crust of efflorescent limestone, and when this layer was broken through the fossils seen were indeterminable casts; but it was dark before there was an opportunity of searching the rocks, and we had to resume our march at dawn next morning.

We continued across the plateau of scrub-covered limestone, until we reached an alluvial plain at Bigratah or Bugrat; the hillsides around the plain consist of the cream-coloured Derna Limestone

---

[1] The Admiralty Chart represents this wadi as part of a basin of interna drainage, and separated from the sea by a continuous ridge from Messa to Gasr el Migdum. Judging from the levels, the Wadi Khumas probably joins the Wadi Jeraib above the confluence with the wadi from the shrine of Abdul Wahil, and both should discharge northwards; otherwise, it seems improbable that the route should descend into the Wadi Jeraib, instead of keeping on the plateau to the north of it.

[2] We were assured that there was no water between Messa and Merj, except for some small wells in the Wadi Gharib. The Commandant of the Turkish garrison at Messa kindly sent a camel laden with water with us to Gasr el Migdum, to save us from drawing on our own loads. The few Arabs remaining in this district were said to live on scanty supplies of stored water.

yielding the large *Nummulites curvispira*. The track from Bigratah to the plain of Merj crosses a low pass at the height of 1120 feet above sea-level, where the chert-bearing limestones crop out from beneath the Derna Limestones.

The plain of Merj is an alluvial plain exceeding 50 square miles in area; it is bounded on the south-east by an escarpment of the Derna Limestone resting upon the chert-bearing limestone. The town of Merj (generally regarded as the ancient Barca[1]) is situated on a small rise, due to the outcrop of a Priabonian limestone. The plain is bounded on the south-east by a long straight cliff, which has a trend of 52°, and is continued south-westwards along the plain of Silene. This long scarp is formed mainly of Derna Limestone: the cherty limestone is exposed beneath that rock in the north-eastern part of the scarp, near Bigratah. The beds are here dipping south-westwards so that the chert-bearing limestone disappears below the surface; the beds then become horizontal, and then dip south-westwards to a low syncline, of which the axis meets the scarp south-south-east from Merj. Some 5 miles south-west is another low anticline; it is followed by another syncline, and the dip continues to the north-east as far as the wide breach in the fault-scarp made by the Wadi Jebril. So far as I could tell from a distant view, the beds again dip south-westwards, become horizontal, and then the scarp becomes quite low. A higher scarp could be seen behind it, and, judging by its white face, it may also be formed of Derna Limestone.

The long cliff that forms the south-eastern boundary of the plains of Merj and Silene has the aspect of a fault-scarp, for it is remarkably straight in direction; the only projections from it are talus-fans opposite the wadis; there are no spurs or outliers, such as would be expected in an escarpment due to denudation; and its course is not affected by the changes of dip in the limestone.

That this hill-line is a fault-scarp is also shown by the palæontological evidence. The limestone at the wells of Merj contains *Pecten arcuatus* Brocchi, *Lucina* cf. *pharaonis* Bellardi, and *Vulsella crispata* Fischer, and, according to Mr. Newton's determinations, is therefore Priabonian. The characteristic nummulite of the Wells of Merj is identified by Mr. Chapman as *N. gizehensis* var. *lyelli*, whereas the species in the cream-coloured limestone of the Merj scarp is *N. gizehensis typica*. Hence the evidence of the foraminifera agrees with that of the mollusca, that the limestones at Merj, which occur at levels ranging from 835 to 850 feet, belong to a higher horizon than the limestone at the level of 1000 to 1240 feet in the hills, 2 miles south of the town.

---

[1] Barca, however, was at Ptolemeta, according to Smith & Porcher, 'History of the Recent Discoveries at Cyrene' 1864, p. 4, and G. Dennis, 'On Recent Excavations in the Greek Cemeteries of the Cyrenaica' Trans. R. Soc. Lit. ser. 2, vol. ix (1870) pp. 141, 156.

(*f*) Merj to Ptolemeta.

To determine the succession of the rocks in this part of Cyrenaica, a traverse was made from the plateau-scarp south of Merj to the coast, near its ancient port, Ptolemais or Ptolemeta.

The relations of the rocks between the plain of Merj and the Wadi Hamema, through which we descended to the shore, are uncertain, as, owing to a misadventure, I had to return to Merj by a night journey. The general section from the plateau south of Merj to the sea at Ptolemeta is illustrated by fig. 3 in Pl. XLII.

The coastal plain near Ptolemeta consists of dunes along the shore, of large delta-fans before the mouths of the wadis, and of wide sheets of alluvium in the intervening depressions. The delta-fan, by which the track from Merj to Ptolemeta reaches the coastal plain, rises to the height of 340 feet. The rocks above it are chert-bearing limestones and marls, belonging to the Apollonia Limestone Series, which continue up to the level of over 940 feet. The rocks are dipping northwards, in places as much as 25°, the steep dip being doubtless due to the proximity of the Tokra Fault, although there may be parallel faults which I did not detect.

The rocks crossed during the ascent on to the plateau from the shore (see Pl. XLII, fig. 3) begin above the delta-fan, at the level of 340 feet, with a dark-grey, compact, dolomitic and siliceous limestone. The rock is succeeded above by a chalky granular limestone with some black grains, which microscopic examination shows to be glauconite. This rock, at the height of about 440 feet, includes an oolitic band, in which Mr. D. P. Macdonald has recognized well-preserved echinoid spines, nullipores, and foraminifera. A similar rock occurs in the chalky limestone at Wadi Nagr, west of Derna.

This rock is succeeded by a compact, unfossiliferous, chalky limestone with a rough granular surface. Mr. Macdonald describes it as containing some calcite crystals and occasional grains of quartz.

Then follows, at the level of from 500 to 550 feet, a series of compact chalky limestones with some grains of glauconite. Mr. Macdonald found in the chalky base some Globigerinæ, sponge-spicules, and a holothurian plate. The rock includes some layers of marl and nodules of chert.

At the level of 620 feet the track crosses a small col into the Wadi Hamema, which has beheaded the gully followed by the route to Ptolemeta. At this level and up to over 650 feet, the rock is a siliceous limestone with abundant chert-nodules. The matrix of this rock, according to Mr. Macdonald, consists of a close calcareous paste with some grains of quartz and glauconite, and it also contains *Globigerina* and a holothurian plate. The chert-bearing rocks are exposed up to the height of 950 feet.

The northern part of this series of beds consists of chalky limestones like those of the Wadi Nagr, and they belong to the upper portion of the Apollonia Limestone Series. The limestones from the level of 500 to 600 feet containing the large chert-nodules represent the lower part of the same series.

The divide between the Wadi Hamema and the plain of Merj, at the level of about 1100 feet, is formed by some shelly limestones from which Mr. Newton has identified the Miocene *Anadara turonica*: whence we may infer that the Apollonia Limestones, which are exposed in some dry cisterns, are overlain by Miocene beds. The simplest explanation of the occurrence of these beds in this position would be that they were deposited unconformably upon the Apollonia Limestones; but I saw no evidence of their actual relations.

The cherts are also exposed on the northern slopes of the divide, between it and the Pleistocene loams of the plain of Merj. Some of the shelly beds near the pass may belong to the Slonta Limestones, which are certainly exposed at Merj, as shown by both mollusca and foraminifera.

The Priabonian or Slonta Limestones occur at the wells of Merj at the level of only 850 feet, while the Derna Limestone rises in the face of the plateau 2 miles to the south to the height of 1240 feet. The Slonta Limestones at Merj must, therefore, have been lowered either by a fault or by a sharp fold; and the general evidence is clear that the movement was a fault.

(*g*) Merj to Benghazi.

The journey from Merj to Benghazi being hurried, there was only time for a general determination of the rocks close beside the route. The track crosses the Merj alluvium for 2½ miles to the south-west and then a low ridge of limestone about 6 miles wide, which separates the plain of Merj from the still larger, but less regular, plain of Silene. This limestone ridge rises to the height of about 1130 feet, or about 300 feet above the plain of Merj. The rock is not well exposed, being covered by a red soil and *Thuya*-scrub; but at 4 miles from Merj there are exposures of a limestone with large nummulites, which no doubt belongs to the Derna Limestones, and is continuous with the rocks that bound both sides of the plain of Merj. I could find no chert, except one or two artificial flakes which had probably been carried there. From the summit of this limestone ridge there is a slight fall to the plain of Silene, over which we marched for 30 miles. Its north-eastern part is higher than the plain of Merj; but it slopes gradually to the south-west, and the outlets of its streams are doubtless in that direction. It is less level than the plain of Merj, consisting rather of undulating steppes covered with a loamy soil, and passing into the limestone downs gradually on all sides, except where it meets the Merj fault-scarp. The surface is wind-swept, and numerous vertical columns of dust travelled across it. The stream banks consist of alluvium, which weathers like lœss; they stand up in low vertical cliffs, and the streams, when they run, are interrupted by small waterfalls. The chief deposit is a brown loam, interstratified occasionally with beds of limestone-gravel. A well at Mletania has been sunk through the alluvium to the depth of 135 feet, and

it is situated only a mile from the border of the plain, there about 6 miles wide. Much of the ground has been cultivated, especially in depressions where soft loam has been collected as rain-wash. Near the shrine or marabut of Ahmeda, the loam is covered with slabs of secondary limestone showing that the alluvium is thinner there; and blocks of limestone resembling the Derna Limestone occur on a ridge, which projects from the downs into the western side of the plain. The surface of this ridge is littered with slabs of efflorescent limestone.

I could find no exposure of the chert-bearing limestones there; but, after crossing the nummulitic limestones for a couple of miles, we found that chert-nodules became abundant and then cherty limestones appeared on the surface. The first specimens of these cherts were much altered by secondary action, and the cherts were chalcedonic. At Smuta there is an outcrop of a shelly siliceous limestone, near the ruins of a Roman fort. The fossils found are, however, unfortunately indeterminable.

After crossing the watershed between the plain of Silene and the direct drainage north-westwards to the Mediterranean, we observed that the country became more irregular, owing to the numerous, deep, stream-cut ravines. The rock at the edge of the plateau overlooking the coastal plain contained many casts of shells, but no determinable fossil was collected. Beneath the shelly limestone occurred a limestone breccia, including pebbles of black limestone. A steep gully leads from the plateau to the coastal plain, near the ruin of an old fort, at the height of about 450 feet above the sea, and some 16 miles east from Benghazi. The face of the plateau has been much denuded, but presents the aspect of a fault-scarp. The rocks at its foot are pinkish and white compact limestones, containing fragments of *Scutella* and a thick massive *Clypeaster*. As the camels had already gone some distance ahead, I was unable to collect any complete specimens, though the sketches of some of the fossils indicate that the beds are Miocene, and probably Middle Miocene. The *Scutella* Limestone is exposed farther west in bosses, polished by wind erosion. Nearer Benghazi, these Miocene limestones are covered by a younger limestone, of which the characteristic shell has been determined by Mr. Newton as *Cerastoderma edule* (Linn.), and the rock is either late Pliocene or more probably early Pleistocene in age. The older limestone was still visible occasionally in depressions in the coastal plain, and in the solution-cauldrons occupied by the Garden of the Hesperides and the cave known as the River of Lethe. Nummulites have been recorded from this limestone by the Archduke Ludwig Salvator,[1] and G. B. Stacey called the rock a 'Tertiary limestone.'[2] The specimens collected there do not contain nummulites, but a virletiform *Ostrea*, which suggests the Helvetian age of the rock.

---

[1] 'Yacht-Reise in den Syrten 1873' Prag, 1874, p. 52.

[2] 'On the Geology of Benghazi, Barbary' Q. J. G. S. vol. xxiii (1867) p. 384; he collected some fossils in the limestone which were not specifically determined, and found *Cardium edule* on the surface (*ibid.* p. 386).

Near Benghazi the lower limestones have sunk beneath sea-level, and the beds exposed around the town are recent dune-limestones containing common Mediterranean shells, such as *Glycymeris glycymeris* (Linn.), *Codakia pecten* (Lam.), *Ostrea edulis* (Linn.), *Cheliconus mediterraneus* (Hwas), etc. Behind the dune-limestones and the dunes to the north of the town are wide sheets of alluvium, which has been deposited in lagoons that are still flooded at intervals and used as salt-pans.

IV. CLASSIFICATION AND CORRELATION OF THE CYRENAICAN ROCKS.[1] (Continued on p. 598.)

The field evidence, including a preliminary determination of some Echinoids, suggested during the traverse of Cyrenaica the following classification of the rocks:—

Pleistocene.	Various alluvial deposits, coastal limestones, etc.
Miocene	*Scutella* Limestones, east of Benghazi, and Gubah-Birlibah Limestones.
Lower Kainozoic.	Cyrene Limestones (Aquitanian). Slonta Limestones. Derna Limestones. Apollonia (chert-bearing) Limestones.

The most surprising geological result of the journey was the comparative rarity of Miocene beds. They are so well developed in Western Egypt, as at Siwa and on the coast near Mersa Tobruk, that the prevalent opinion in recent years (see p. 576) had been that Cyrenaica was mainly composed of Miocene rocks. The subsequent study of the collections has, however, even lessened the area that in the field I was disposed to assign to the Miocene, as the species of *Amphiope*, a genus especially found in that system, has to be referred back, owing to its associated fossils, to the Eocene.

The correlation of the rocks of Cyrenaica depends upon the fossils, mainly mollusca, foraminifera, and echinoids, upon which reports have been prepared by Mr. R. B. Newton, Mr. F. Chapman, and myself.

The oldest rocks exposed occur in the Tokra fault-scarp, east of Benghazi; they are somewhat lower than the chert-bearing limestones, but no determinable fossils were obtained from them.

---

[1] Owing to the varying nomenclature of the Middle and Lower Eocene Kainozoic Series, the following synopsis may be convenient for reference:—

Miocene		Tortonian	Vindobonian.
		Helvetian	
		Burdigalian or Langhian.	
Oligocene		Aquitanian (often included in the Miocene).	
		Stampian or Rupelian	Tongrian (sometimes used to include Stampian).
		Sannoisian or Ligurian	
Eocene	Upper.	Priabonian or Ludian (sometimes included in the Oligocene).	
		Bartonian.	
	Middle.	Parisian (Lutetian); Mokattam Series of Egypt.	
	Lower.	Londonian or Ypresian; Libyan Series of Egypt.	
		Suessonian, Thanetian or Landenian.	

III. LISTS OF FOSSILS.

L.E.=Lower Eocene.
M.E.=Middle Eocene.

Ol.=Oligocene.

Bt.=Bartonian.
Lt.=Lutetian.

Aq.=Aquitanian.
St.=Stampian.

Foraminifera.	Horizon.	Derna.	Ain Sedja.	Bint.	Wadi Nagr.	Sidi Rof Diasiasia.	West of Mersa Susa.	Cyrene escarpment, east of Ain Sciahat.	Cyrene, below Ain Sciahat.	East of Slonta.	North of Roman Camp, north-west of Slonta.	Wells at Merj.	Bigratah.	
Nummulites (*Paronia*) *curvispira* Menegh.	M.E.	×	×	×	× above camp	...	×	×	...	×	×	×	×	Foot of upper cliff of Cyrene Limestone, west of Ain Hafra; about 5 miles north-east of the Shrine of Sidi Mahomet Mahridi, east of Slonta.
N. curvispira, var. nov., Chapm.	M.E.	...	...	...	...	...	...	...	×					
N. gizehensis Ehr.	M.E.	×	...	...	...	...	×	...	...	...	...	...	×	
N. gizehensis, var. *lyelli* de la Harpe	M.E.	...	...	...	...	...	...	× 1560′ & −1560′	×	×	×	×		
N. gizehensis, var. *pachoi* de la Harpe	M.E.	...	...	...	...	...	...	...		...	...	...	...	About 5 miles north-east of the Shrine of Sidi Mahomet Mahridi, east of Slonta.
N. gizehensis, var. *viquesneli* Arch. & H.	L.E.	...	...	...	...	× Ech. L.								
N. rouaulti Arch.	M.E.	×												
N. ehrenbergi de la Harpe	M.E.	...	×											
N. beaumonti Arch.	M.E.	...	...	...	...	...	...	...	...	...	...	...	...	Gasr el Migdum.
N. subbeaumonti de la Harpe	M.E.	...	...	...	...	...	×							

N. subdiscorbina de la Harpe	M.E.	...	...	...	...	...	× 530′	...	...	×	...	...	...	East of Ain Hafra—1100 feet.
N. subramondi de la Harpe	? L.E.	...	...	...	...	...	...	...	...	...	...	...	...	North of Cyrene; above camp at Ain Sciahat.
N. fraasi de la Harpe	M. or U.E.	...	...	...	...	...	...	...	...	...	...	...	...	Messa. In matrix of ***Pecten arcuatus***.
Operculina libyca Schwager	L.E. to Mioc.	...	...	×	×	×	...	×		...	...	...	...	With *Clypeaster* ***biarritzensis*** var. *trotteri*.
Orthophragmina pratti (Mich.)	Bt. or Lt.	...	...	...	×									
Lepidocyclina elephantina M.-Chalmas	Aq. or St.	...	...	...	...	...	...	...	...	...	...	...	...	Wadi Umzigga; Birlibah.
Miliolina contorta (Orb.)	M.E.	...	...	×										
M. lucens Schwager	M.E.	...	...	×										
M. ferussaci (Orb.)	M.E.	...	...	×										
M. trigonula (Lam.).	Recent & fossil.	...	...	...		...	...	...	...	...	...	...		Scarp west of Ptolemeta.
Polymorphina compressa Orb.	M.E.	...	...	×										
Truncatulina culter (P. & J.)	M.E.	...	...	×										
Tr. lobatula (Orb.).	M.E.	...	...	×										
Tr. ungeriana (Orb.)	M.E.	...	...	×										
Anomalina ammonoides (Reuss)	M.E.	...	...	×										
A. insecta Schwager	M.E.	...	...	×										
Pulvinulina repanda (F. & M.)	M.E.	...	...	×										
P. elegans (Orb.).	M.E.	...	...	×										
P. kersteni Reuss	L.E.	...	...	...	...	...	...	×						
Bolivina textilarioides Reuss	L.E.	...	...	...	...	...	...	×						
Polystomella striatopunctata (F. & M.)	M.E.	...	...	×										

Echinoidea.	Horizon.	Ain Sciahat.			[Tongr. = Tongrian. Helv. = Helvetian. Langh. = Langhian.]
		Cyrene Limestones.	Slonta Limestones.	Derna Limestones.	
Clypeaster biarritzensis, var. *trotteri* nov.	U.E.	×			
Fibularia luciani (Lor.)	M.E.	...	...	×	Foot of Cyrene Escarpment.
Scutella tenera Laube	Tongr.	...	×	...	Labruk ; Bir Hu.
Amphiope duffi, sp. nov.	...	...	×	...	Sidi Rof Diasiasia.
Amphiope sp.	...	×			
Echinolampas chericherensis Gauth.	U.E.	...	×	...	Slonta Limestones near Labruk; Safsaf; Cyrene; below Ain Sciahat; Cyrene to Slonta; Messa; Wadi Gharib.
Echinolampas discus Des.	Aq.	×			
Hypsoclypeus hemisphericus (Greg.)	Helv.	...	...	...	Birlibah.
Hemiaster scillæ Wright	Aq. to Langh.	×			
Schizaster ederi, sp. nov.	...	×			
Sarsella lamberti, sp. nov.	...	×			

Holothuroidea.

Holothuria plates were recognized by Mr. D. P. Macdonald in the chalky limestone of the Apollonia Series west of Ptolemeta, and in the Derna Limestones near Merj.

Ostracoda.

	Horizon.	
Loxoconcha cyrenaica, sp. nov.	M.E.	Wadi Nagr.
Cythere striato-punctata (Rom.)	M.E.	
? *Cythere wetherelli* Jones	U.E. to Ol.	*Clypeaster* Bed east of Ain Sciahat.

Cirripedia.

Balanus concavus Bronn	Miocene.	Gubah.

Mollusca.

Pleistocene.	Bommansur, south of Derna.	Plain east of Benghazi.	West of Ptolemeta.
Hygromia sordulenta (Morelet)	×		
Helicella tuberculata (Conrad)	...	×	
Ostrea edulis Linn.	...	×	
Glycymeris glycymeris (Linn.)	...	×	
Glycymeris pilosa (Linn.)	...	...	×
Cardium tuberculatum Linn.	...	...	×
Cerastoderma edule (Linn.)	...	×	
Mactra stultorum (Linn.)	...	×	
Jagonia pecten (Lam.)	...	×	
Loripes lacteus (Linn.)	...	×	
Cerithium cf. *vulgatum* Bruguière	...	×	
Columbella rustica (Linn.)	...	×	
Cheliconus mediterraneus (Hwas in Bruguière)	...	×	

Mollusca *(continued).*

Miocene.	Gubah.	Cave of 'River Lethe.'	Plain east of Benghazi.	Between the plain of Merj and Wadi Hamema.
Alectryonia plicatula (Gmel.)	×			
Alectryonia virleti (Desh.)	...	×		
Gigantopecten ziziniæ (Blanckenhorn)	...	...	×	
Anadara turonica (Dujardin)	...	...	...	×
Strombus coronatus (Defrance)	×			

Aquitanian.	East of Shrine, east of Slonta.	Ain Sciahat, above camp.	Ain Sciahat.	Birlibah.	West of Labruk.	
Ostrea cf. *caudata* Münster	×					
Ostrea crassicostata Sowerby	×	...	...	...	...	W. of Lamludeh.
Spondylus cisalpinus Brongniart	...	×				
Pecten vezzanensis Oppenheim	...	...	×			
Pecten cf. *pasini* Meneghini	...	...	×	×		
Æquipecten zitteli Fuchs	×	×	...	...	×	
Æquipecten camaretensis (Fontannes)	...	×				
Æquipecten scabrellus (Lam.)	...	×				
Æquipecten haueri Michelotti	...	...	×			
Oopecten rotundatus (Lam.)	...	×	×	...	×	Wadi Umzigga.

Priabonian.	Mersa Susa.	Kuff Narbea, north of Wadi Firyah.	Near Slonta.	North of Slonta.	Messa.	Wells at Merj.	South-west of Merj.	
Ostrea cf. *ventilabrum* Goldfuss	...	...	×	×	...	...	×	Near Bint, E. of Derna.
Pecten arcuatus (Brocchi)	×	×	×	...	×	×	×	Near Bint, E. of Derna.
Æquipecten cf. *deletus* (Michelotti)	...	...	...	...	...	...	...	Derna.
Æquipecten cyrenaicus, sp. nov.	...	...	...	...	...	...	...	Above camp at Ain Sciahat.
Vulsella cf. *crispata* P. Fischer	...	...	...	...	...	...	×	
Vulsella eymari Oppenheim	...	...	×					
Spondylus sp. (cf. *rouaulti* d'Arch.)	...	...	...	×				
Trachycardium cf. *granconense* Oppenheim	×							
Lucina cf. *pharaonis* Bellardi	...	×	×	×	...	×	...	Pass N. of Wadi Khumas.
Lucina cf. *nokbaensis* Oppenheim	...	...	...	...	...	...	...	Wadi Nagr, first camp west of Derna.
Corbis lamellosa (Lam.)	...	...	×					
Mactra cf. *fourtaui* Cossmann	...	...	...	...	...	...	...	Pass N. of Wadi Khumas.
Cardita (cf. *acuticostata* Lam.)	...	...	...	...	...	...	...	Pass N. of Wadi Khumas.
Euspira possaguensis Oppenheim	...	...	...	...	...	...	...	East of Ain Hafra.
Ampullina crassatina Lam.	...	...	...	...	...	...	...	Lamludeh.
Rostellaria cf. *ampla* Sol.	...	...	...	...	...	...	...	West of Shrine of Sidi Abdullah; south-east of Messa.
Gisortia gigantea (Münst.)	×							
Vasum cf. *frequens* Mayer-Eymar	...	...	...	...	×			

Parisian.

Ostrea sp. (cf. *O. gigantea*)	Near Ain Sciahat.

They probably represent part of the Lower Eocene or Libyan Series of Egypt. The chert-bearing Apollonia Limestones also yielded no determinable molluscs or echinoids, but their infraposition to the Derna Limestone shows that they correspond to the chert-bearing Upper Libyan Limestones of Egypt. They are succeeded above by the Derna Limestone, which is shown by its beautifully preserved foraminifera to be the equivalent of the Lower Mokattam Limestone in Egypt, and is therefore of Middle Eocene age. The Slonta Limestones, a stratified series above the Derna Limestone, according to Mr. Chapman's identification of the fossils, are also Middle Eocene. But Mr. Newton reports that the mollusca are Priabonian, which is regarded either as the uppermost series of the Eocene or the lowest of the Oligocene.

The evidence of the echinoids agrees with that of the mollusca. One of the most characteristic beds in the Slonta Series yielded many specimens of *Echinolampas*; but I have been unable to recognize among them any specimen, either of *Echinolampas crameri* or of *E. africanus*, the characteristic Upper Mokattam species: the Echinolampids certainly have Upper rather than Middle Eocene affinities.

The supposition that the Slonta Limestones may represent the Upper Mokattam stage is, on the other hand, supported by some stratigraphical considerations. Thus, at or near the top of the Slonta Limestones is a widespread horizon containing reef-building corals. The specimens obtained were casts, and they have not yet been closely examined; but the development of the reef-corals at this horizon must be due to a shallowing of the sea in Cyrenaica, and this change may have been contemporary with the growth of the reefs of *Orbicella* and other corals in the Upper Mokattam Beds of Egypt.

The Upper Mokattam Beds in Egypt are succeeded by freshwater and terrestrial deposits, and the only quartz-pebbles found in Cyrenaica, except along the coast, were obtained at Gasr el Migdum, in a bed a little above the coral-reef horizon. This pebble-bed, and the marl containing flattened stem-like fragments that forms the springs at Cyrene and Messa, may represent a stratigraphical break corresponding to the Egyptian freshwater beds; and there is clearly a gap in the succession at or a little above this horizon, since no representative of the Lower Oligocene (Tongrian) was found. The Slonta Beds are succeeded by the Cyrene Limestone, which is referred to the Upper Oligocene (Aquitanian).

If the reef-coral limestone in Cyrenaica is on the same horizon as that of Egypt, then the Slonta Beds would be Middle Eocene, and the gap in the succession in Cyrenaica would include both the Upper Eocene and the Lower Oligocene.

That the Derna Limestone is Middle Eocene is undoubted. It is overlain by a hard or rough-weathering limestone, some layers of which contain so many echinoid-plates and spine-fragments as to suggest for it the name of the Echinoid Limestone. Some of the plates came from regular echinoids, but I unfortunately did not collect sufficient for generic determination. Above this Echinoid Limestone is a soft white marl containing *Fibularia*

luciani; hence this bed and the underlying Echinoid Limestone may both be included in the Middle Eocene. The *Fibularia* Bed is succeeded by a series of limestones which, so far as I saw, were resting conformably upon it. These limestones include the white to cream-coloured nummulitic limestone, in which have been excavated the tombs of the northern necropolis of Cyrene. Mr. Chapman refers the foraminifera in this rock to the Middle Eocene. It does not, however, contain the typical *N. gizehensis* found in the Derna Limestone, but the variety *lyelli*; and that variety is also found in the brown-weathering, stratified limestones at Slonta. There and elsewhere the variety *lyelli* is associated with Priabonian, or at least Upper Eocene, mollusca and echinoids.

I am therefore forced to the conclusion that the Slonta Limestone should be included in the Upper Eocene, and regarded as Priabonian. This view involves the correlation of the hard, brown-weathering limestones of the Slonta Downs with the soft, cream-coloured, nummulitic limestone of the northern necropolis of Cyrene. But, as the two formations both occur between the Cyrene Limestone and the Derna Limestone, and as they both contain the same variety of nummulite, they must be approximately on the same horizon. The difference in their lithological characters is probably due to the beds at Cyrene having been deposited farther from land. The occurrence of the variety *lyelli* may be due to its survival, owing to favourable bathymetric conditions.

The identification of the Slonta Limestone as Upper Eocene and Priabonian introduces one important difference between the stratigraphical succession in Egypt and in Cyrenaica. The coral-limestones of the two countries must be at different horizons; but what is more remarkable is that the great gap in the succession in Cyrenaica would be later than that in Egypt, if the usually accepted age of the *Palæomastodon* Beds of Egypt be correct. The date of that fauna has been the subject of considerable discussion. According to Dr. Andrews,[1] these *Palæomastodon* Beds are Bartonian; Prof. Depéret,[2] on the other hand, from the resemblance of Andrews's *Ancodon gorringei* from the Fayûm to the *Brachyodus cluai* from the Ebro Valley, holds that the Fayûm Beds are Oligocene, and belong either to the base of the Stampian or to the top of the Sannoisian. Dr. P. Oppenheim[3] has since reaffirmed his acceptance of the Eocene age of the Fayûm beds, and says that they are at the highest, Ludian, that is, Priabonian.

If Dr. Andrews's and Dr. Oppenheim's conclusions be correct, then the marine deposits ended in Egypt at the close of the Middle Eocene or Parisian (Lutetian), while the sea still covered Cyrenaica, which only emerged in the Lower Oligocene. But, if Prof. Depéret be right, the gap in the marine succession of deposits in Cyrenaica occurred at the same time as in Egypt.

---

[1] C. W. Andrews, 'A Descriptive Catalogue of the Tertiary Vertebrata of the Fayûm, Egypt' British Museum, 1906, pp. ix, x.

[2] Ch. Depéret, 'Sur l'Age des Couches à *Palæomastodon* du Fayoum' Bull. Soc. Géol. France, ser. 4, vol. vii (1907) pp. 193–94; also *ibid.* pp. 455–56.

[3] P. Oppenheim, 'Observations sur l'Age des Couches à *Palæomastodon* du Fayoum' Bull. Soc. Géol. France, ser. 4, vol. vii (1907) pp. 358–60.

Some of the evidence of the Cyrenaican fossils is consistent with Prof. Depéret's view that the Egyptian mammalian beds are later than the dates usually accepted: thus *Pecten arcuatus*, the most widespread mollusc in the limestones ascribed to the Priabonian, is also found in the Tongrian; and the *Amphiope*, found at several localities, is not an Eocene genus. Its presence led me in the field to regard the beds containing that genus as, at the earliest, Tongrian; but the evidence of the associated nummulites and mollusca, as also the Upper Eocene aspect of the accompanying Echinolampids, renders it advisable to regard the presence of *Amphiope* as due to an unusually early occurrence of that genus. Otherwise, though the acceptance of *Amphiope* and *Pecten arcuatus* as Tongrian would approximate to Prof. Depéret's views, it would increase the difference between the dates indicated by the foraminifera and by some of the other fossils.

It may be suggested that the simplest explanation of the conflict of evidence is that the specimens were mixed after they were collected. The mixture was however Nature's, not mine; for some of the fossils which indicate different dates were cut from the same hand-specimen.

It therefore seems probable that, because of varying bathymetric conditions, there was an intermingling of the Middle and even Lower Eocene foraminifera, *Nummulites curvispira* and *N. gizehensis*, with Upper Eocene mollusca; but, on the reappearance of *N. gizehensis* it was represented by var. *lyelli*, the nummulite characteristic of the limestones at Slonta and of the soft limestone excavated into the tombs at Cyrene.

The distribution of the chief nummulites in question is as follows (with their range in the corresponding horizons in Egypt and adjacent parts of Asia, quoted from Dr. Blanckenhorn's table [1]):—

		Dr. Blanckenhorn's Table.	
Cyrene Limestones.	*Nummulites subramondi* and *Operculina libyca*.	Lower Oligocene.	*N. intermedia* and *N. biarritzensis*.
Slonta Limestones.	Coral-limestone—*N. beaumonti*. Limestone of the Cyrene Tombs and *Echinolampas* Beds of Slonta—*N. gizehensis* var. *lyellii*, *N. curvispira*, *N. subdiscorbina*, *N. intermedia*, and *Operculina libyca*.		
	Fibularia Limestone—*N. curvispira*. Echinoid Limestone—*N. subdiscorbina* and *N. gizehensis* var. *viquesneli*.	Upper Mokattam.	*N. subdiscorbina* and *N. beaumonti*.
Derna Limestones.	*N. gizehensis*, *N. curvispira*, *N. ehrenbergi*, and *N. rouaulti*.	Lower Mokattam.	*N. gizehensis*, *N. curvispira*, *N. beaumonti*, and *N. subdiscorbina*.
Apollonia Limestones.	*N. subdiscorbina*.	Upper Libyan.	
		Lower Libyan.	*Operculina libyca*, *N. biarritzensis*.

---

[1] 'Neues zur Geologie & Paläontologie Ægyptens, II. Das Paläogen' Zeitschr. Deutsch. Geol. Gesellsch. vol. lii (1900) facing p. 406.

The *Nummulites* and *Operculina libyca*, which lived from the Lower Libyan to the Miocene, have therefore a somewhat variable range in age, and their distribution must be influenced by bathymetric conditions.

Above the Priabonian or Upper Eocene rocks of Cyrenaica there appears to be a gap in the succession, as the next beds recognized belong to the Upper Oligocene or Aquitanian. The limestones of Wadi Umzigga and Birlibah contain *Lepidocyclina elephantina*, which Mr. Chapman assigns to the Middle or Upper Oligocene (Stampian or Aquitanian); the mollusca from the same limestone are identified by Mr. Newton as Aquitanian: hence the rocks may be accepted as Aquitanian. They are, therefore, of nearly the same age as the limestones at Cyrene, which are the best representatives in Cyrenaica of the Aquitanian Series.

At Gubah, west of Wadi Umzigga, the rocks are Miocene, and probably Helvetian; and as I found an Echinoid of that age near Birlibah, there are apparently Miocene outliers on the *Lepidocyclina* Limestones.

The Miocene rocks were not once seen resting directly upon the older rocks. They form the plains at the foot of the Tokra scarp, east of Benghazi; but there they have been faulted down against the Lower Eocene beds. Some shelly limestones, from which Mr. Newton has identified the Miocene *Anadara turonica*, occur on the divide between the plain of Merj and the wadis leading to the coast near Ptolemeta. They lie upon the Apollonia Limestone. The Gubah Limestones are also probably faulted down against the rock which forms the plateau near Zawiah Charrah; but we obtained no definite evidence as to their relations, as we had been asked to travel quickly and with special care to avoid arousing suspicion during that stage of the journey.

The sequence of rocks in Cyrenaica is, therefore, more varied and complex than was anticipated. The Miocene rocks, instead of occupying the whole country, are sparsely represented, and Cyrenaica consists essentially of a vast block of Eocene limestone. This rock is capped by some outliers of Oligocene and Miocene; while some Miocene limestones have been faulted against its western foot, and it is fringed by low-level, marine, Pleistocene limestones.

The suggested classification and correlation of the Cyrenaican beds and their relations to those of Egypt, Tunis, and Malta, are shown in the table on p. 602.

The stratigraphical succession in Cyrenaica differs, therefore, from that in Egypt and Tunisia, owing to the continuity of the marine rocks in Cyrenaica and their deposition farther from land. The most striking feature in their lithology is the paucity in mechanically-derived sediment—a fact brought out clearly by a careful study of a series of microscopic sections made by Mr. D. P. Macdonald. The series must include nearly 3000 feet of strata, which consist of limestones almost entirely composed of organically formed material. There are occasional beds of limestone-breccia,

	Cyrenaica.		Egypt.	Central Tunisia.	Malta.
PLEISTOCENE.		Sand-dunes, lagoon-clays, alluvium and delta-fans. Calcareous tufa of Derna. *Cerastoderma-edule* Limestone, east of Benghazi.			
MIOCENE.					
Upper—Tortonian.		None.			Upper Coralline Limestone.
Middle—Helvetian.		*Scutella* Limestones at the foot of the Tokra scarp. Gubah Limestones.	Limestones with *Scutella*, *Clypeaster subplacunarius*, *Ostrea virleti*, etc. of Siwa and Marmarica.	Sandstones and conglomerates with *Ostrea crassissima*, *Pecten fuchsi*.	Greensand.
Lower—Burdigalian		None.		Coarse white sandstone with *Scutella subrotunda*.	Blue Clay. Upper *Globigerina* Limestone.
OLIGOCENE.					
Upper—Aquitanian.		Cyrene Limestones at Cyrene, north-east of Slonta, Labruk, Lamludeh, Birlibah, Wadi Umzigga, etc.		White sandstone of G. Gebil.	Lower *Globigerina* Limestone.
Lower—Tongrian.		None.	*Lithothamnion* Limestones of Aradj, and basalts of the Fayûm.		Lower Coralline Limestone.
EOCENE.					
Upper—Priabonian.	Slonta Limestones.	Coral-limestone at Wadi Firyah, Labruk, etc. Tomb Limestone at Cyrene and *Echinolampas* Bed at Slonta—with *Nummulites gizehensis* var. *lyelli*.		Clays and sandstones with *Pecten arcuatus*, *Echinolampas chericherensis*, *Clypeaster biarritzensis*.	
Middle—Mokattam Series.	Derna Limestone.	*Fibularia* Limestone at Cyrene. Echinoid Limestone. Cave Limestone with *N. gizehensis typica* and *N. ehrenbergi*.	Coral-limestone of the Fayûm: limestones and marls near the Pyramids. Limestones and marls, with the typical Nummulite Limestone.	Marls with *Echinolampas goujoni* and *Ostrea bogharensis*.	
Lower—Libyan.	Apollonia Limestone.	The Chert-bearing Series. Shelly limestone below the Apollonia Limestone.	White limestone with chert-nodules. Limestones and marls of Farafra and Khargah.	*Globigerina* Limestones with chert-nodules and *Nummulites rollandi*. Nummulite Limestone with phosphatic chalk.	

but I only remember finding quartz-pebbles once, and sand-grains in the limestone are rare. Some of the limestones are argillaceous, or include layers of marl; and this material is composed of a very fine clay. We saw no representatives of the terrestrial and freshwater deposits of Egypt, or of the abundant sandstones and clays found in the corresponding rocks of Tunisia.

The Cyrenaican limestones must have been deposited mainly in water of moderate depth. The rocks which indicate the deepest water are the fine-grained chalky *Globigerina* Limestones, which form the upper part of the Apollonia Limestones, west of Ptolemeta, and are also exposed at the Wadi Nagr. During the deposition of the Slonta Series the sea was shallower near Slonta than at Cyrene, for clastic material becomes more abundant as the beds are traced southwards; hence land doubtless existed in that direction, and if no considerable river discharged on that coast it need not have been far away. The widespread coral-reef limestones near the top of the Slonta Series indicate a shallowing of the sea, and the area may have been raised above sea-level during Lower Oligocene times; for the Slonta Series of Priabonian age is apparently succeeded by Aquitanian limestones.

Another gap succeeded the Aquitanian; for the next beds are shallow-water Middle Miocene limestones, which are widely developed on the coastal plains east of Benghazi, and are preserved in occasional fragments on the summit of the Cyrenaican plateau.

The Cyrenaican sequence resembles the Maltese in the persistence of marine conditions. The Maltese beds, however, began later, as the oldest is Tongrian, while the latest is Tortonian. The *Globigerina* Limestones of Malta were probably laid down in deeper sea—Sir John Murray's estimate for them is 1000 fathoms—than any in Cyrenaica; but the chalky limestones of the Apollonia Series were probably formed in water not much shallower. The long continuity of a variable marine series is a feature common to the geology of both Malta and Cyrenaica.

V. The Tectonic Geology.

The two essential facts in the structural geology of Cyrenaica are, that pre-Kainozoic rocks are unknown there[1]; and that all its rocks are marine limestones, which, although raised in places to 2500 feet above sea-level, are, except in the vicinity of the main fault, still horizontal or inclined in broad shallow folds. The country, therefore, has no resemblance either in composition or in structure to the Atlas Mountains. It is essentially a block of Eocene Limestone, capped by some outliers of Oligocene and Miocene, and flanked by Pleistocene. The Eocene rocks, which form the great mass of the country, resemble those of Egypt; but I saw no representative of the Bartonian and Oligocene terrestrial deposits found in Egypt, as in the Fayûm.

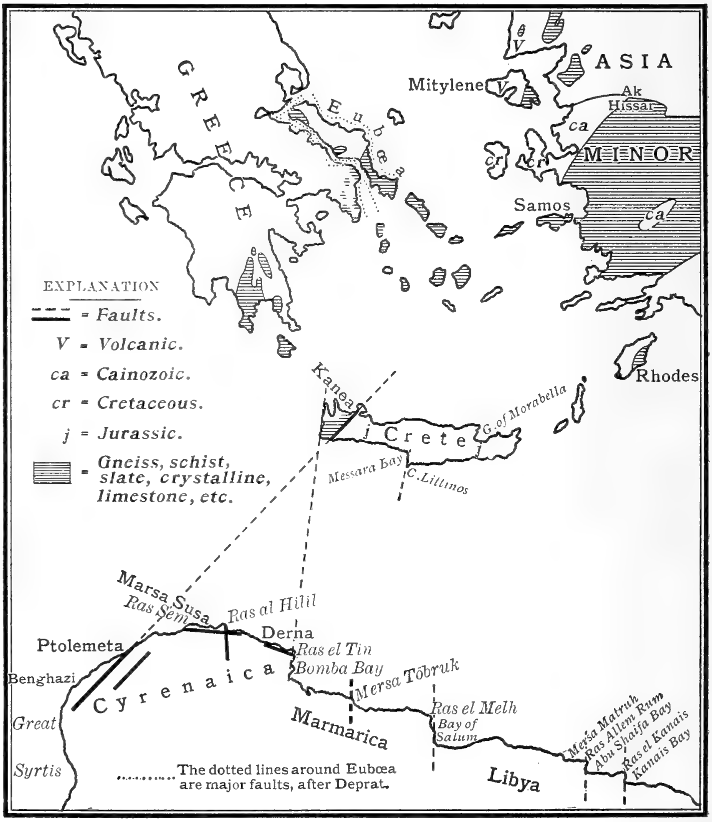
---

[1] The most likely position for Cretaceous rocks is on the lower part of the Tokra scarp.

Cyrenaica may, therefore, be described as a plateau formed by a westward extension of the Eocene limestones of Egypt, and capped by outliers of the Maltese beds.

The Miocene rocks, which, on the coast of Western Egypt, are but little above sea-level,[1] occur in Eastern Cyrenaica at the height of 1100 to 1800 feet; and, while the base of the Derna Limestone,

Fig. 4.—*Sketch-map illustrating the tectonic relations of Cyrenaica.*



[*For* 'Marsa Susa' *read* 'Mersa Susa.']

which is correlated with the Lower Mokattam Beds of Egypt, lies close to the sea-level at Derna, it disappears beneath it farther east. Westward, on the other hand, the Derna Limestone at Mersa Susa extends from about 500 to 1100 feet above sea-level, it

---

[1] They are marked on Dr. Ball's map of Mersa Matruh up to the height of about 200 feet.

rises in the Wadi Khumas to the height of nearly 1800 feet, and its base is from 1000 to 1100 feet above sea-level near the plain of Merj. The main dip is, therefore, from Western Cyrenaica eastwards into Egypt; hence the Cyrenaican plateau may be regarded as the western limb of the Egyptian geosyncline, of which the centre is occupied by the Oligocene basin on the west of the Fayûm.

In Cyrenaica, faults are more important than folds. That some of the main geographical features of the country were due to faulting was suggested by Spratt.[1] He attributed the sharp bends of the coast, as at Ras el Tin, the Syrtis, and the Bay of Salum, as also the variations in the level of the plateau, to the influence of faults. This suggestion was repeated by Dr. Hildebrand[2] in 1904. The general aspect of the country, as seen from the sea, appeared consistent with this hypothesis, which was confirmed by the facts discovered during our march.

The faulting happened so long ago that the actual faults are hidden; for the scarps have been worn back, and the fault-lines covered by talus. The existence of the faults was, however, proved east of Benghazi and near Merj, for in both cases younger rocks have been lowered against older members of the Cyrenaican sequence. The Gubah Limestones have probably also been faulted down against the Eocene limestones.

I expected to find that the step-like descent from Cyrene to the coast was due to two parallel step-faults, the upper cliff at Cyrene being the scarp of one of them. The upper cliff is, however, an escarpment. The platform at its foot is not a repetition of the rock (the Cyrene Limestone) of the upper plateau, but an outcrop of an older, harder limestone, which has resisted denudation. The lower cliff, however, if we judge from the evidence collected near Mersa Susa, is doubtless a fault-scarp; for Mr. Newton has identified the fossils collected on the coastal plain at the foot of the cliff (for list, see p. 597) as Priabonian in age, and they are lying at the foot of cliffs of Lower Eocene chert.

The faults of which I obtained definite evidence may be classified into three main groups, the relations of which are shown in fig. 1 (Pl. XLII) & text-fig. 4 (p. 604).

The first group trends approximately east and west, and forms the scarps seen from the sea behind Mersa Susa, and near Derna. In both cases the evidence for the existence of the fault rests on the identification of the Priabonian limestones at the foot of the cliffs, and lying against the Lower Eocene rocks. It appears probable that the coast-line east of Ras al Hilil may be due to the same fault; and it appears natural to suggest that the long straight lines of the coast in Marmarica, and of the north and south sides of Crete, may also have been determined by faults with the same general trend. (See map, fig. 4.)

The fault east of Derna, which appears to determine the position

---

[1] T. A. B. Spratt, 'Travels & Researches in Crete' vol. ii (1865) App. iv, pp. 375–76.

[2] G. Hildebrand, 'Cyrenaïka als Gebiet künftiger Besiedelung' 1904, p. 7.

of the coast between that port and Ras el Tin, trends about 20° to the south of east. It thus approximates toward the direction of the powerful faults which, as shown by M. Deprat,[1] formed the islands of Eubœa, Andros, and Tinos, and separated Eubœa from the mainland of Greece by the rift-valley of the Talanta and Euripo Channels.

The members of the second group of Cyrenaican faults trend from south-west to north-east. They give rise to the scarps that bound the plains of Merj and Silene, as Upper Eocene limestones at Merj occur at a lower level than the Middle Eocene limestones of the plateau to the south-east of the town. The Merj fault-scarp is parallel to the Tokra fault-scarp, down which we descended on to the coastal plain about 16 miles east of Benghazi. The hills are formed of Lower Eocene rocks, and that the limestones at their foot are Miocene is clear from the large Clypeasters and Scutellas exposed on the wind-swept surfaces. The Tokra fault must have a downthrow of at least 1500 feet. This fault-scarp trends towards Ptolemeta, but its precise course is uncertain. The position accepted for its northern continuation on the map (fig. 4, p. 604) is based on the Admiralty Charts, Eastern Mediterranean (2158 B, corrected to 1907) and Benghazi to Derna (1031, corrected to 1900); but, according to Camperio,[2] the fault-scarp may pass nearer to Tokra, for his map marks the high plateau as reaching nearly to the shore and ending to the east of Tokra in a steep descent which trends from about west-south-west to east-north-east. The Admiralty Charts, however, represent the scarp as passing farther inland on a fairly straight course, from its position east of Benghazi to Ptolemeta. The International Geological Map of Europe (Sheet D VII, 1905) agrees more closely in this respect with the Admiralty Chart than with Camperio's map.

The Tokra scarp, as above accepted, is parallel to the Merj scarp and is in line with the sharp division in Western Crete between the Jurassic rocks and the metamorphic area south of Kanea. The downthrow of the faults would no doubt be on opposite sides in Crete and Cyrenaica; but the coincidence of direction is remarkable, especially as the continuation of this line into Asia Minor separates the downthrown Kainozoic area of the Smyrna district from the metamorphic rocks of the highlands to the south-east of Smyrna and Ak Hissar. This line across Western Crete and from Smyrna to Ak Hissar is almost at right angles to the direction of the Eubœan faults.

The third group of Cyrenaican faults trends approximately north and south. It includes the Gubah Fault, the continuation of which may form the headland of Ras al Hilil. The evidence from this fault supports Spratt's suggestion that the sharp bends of the coast on the western sides of Bomba Bay, of the Bay of Salum, and perhaps

---

[1] J. Deprat, 'Étude Géologique & Pétrographique de l'Ile d'Eubée' Besançon, 1904.

[2] 'Carta Economica della Tripolitana & Cirenaica,' published by the Società di Esplorazione commerciale in Africa, Milan, 1883.

too of Abu Shaifa Bay and Kanais Bay, are also due to faults. The abrupt western ending of Crete along a north-and-south line, and the conspicuous headlands with the same trend, such as Cape Littinos and the western shore of the Gulf of Morabella, may also be due to north-and-south faults. (See map, fig. 4, p. 604.)

The throw of some Cyrenaican faults is very great. The fault behind Mersa Susa had a movement of approximately 1500 feet, and the Tokra fault had a downthrow to the west of at least the same amount. The movements, though extensive, are probably of recent geological date. The best evidence obtained as to their age is from the Tokra scarp. Limestones with *Cerastoderma edule* extend over the coastal plain nearly to the foot of that scarp. I did not see them along the fault-line, but their range inland was probably bounded by it. As the *C.-edule* Beds are late Pliocene or early Pleistocene, the fault-scarp was probably formed before the deposition of these beds; it was certainly later than the *Scutella* Limestone, which is probably of Middle or perhaps Upper Miocene age.

The faults are not necessarily of one age, but they were probably all part of a connected series of movements which apparently began later than the Helvetian and earlier than the *Cerastoderma-edule* Beds. These deposits represent a marine transgression of late Pliocene and early Pleistocene age, which can be recognized in many widespread localities on the northern coasts of Africa. If the Tokra scarp be a continuation of that in Western Crete near Kanea, the south-west to north-east faults would be earlier than those which trend east and west and have determined the northern coast of Cyrenaica; and the fact that we did not find the *Cerastoderma-edule* Beds along the northern coast gives slight support to that hypothesis. Negative evidence from a hurried examination of so small a proportion of the coast is of little weight, but the fact may be mentioned in order to direct attention to this point. The *Cerastoderma-edule* Beds occur on the western coasts of Egypt; and, if they are absent from the northern coast of Cyrenaica, then the faults, by which the last remnant of the land-connexion between Africa and Crete foundered beneath the Mediterranean, took place after the deposition of the early Pleistocene limestones. The land-bridge to Crete would moreover have been limited in width to the area between Ptolemeta and Mersa Matruh, where M. Pachundaki has found the *C.-edule* Beds.

Cerastoderma edule is widely distributed in Algeria and Tunisia, and is referred by M. Georges Rolland[1] to the Upper Pliocene; but, as its main distribution is post-Sicilian, it is safer to regard the *C.-edule* Limestone in Cyrenaica as early Pleistocene, the age accepted for it by Dr. Blanckenhorn[2] and by M. Pachundaki.[3]

---

[1] 'Géologie du Sahara Algérien & Aperçu géologique sur le Sahara, de l'Océan Atlantique à la Mer Rouge.' Chemin de Fer Transsaharien (French Government Report), Paris, 1890, pp. 194-95.

[2] 'Neues zur Geologie & Paläontologie Ægyptens—IV. Das Pliocän- & Quartärzeitalter' Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) table facing p. 308.

[3] 'Contribution à l'Étude Géologique des Environs de Marsa Matrouh (Marmarique)' Revue Internationale d'Égypte, vol. iv (1907) pp. 4 & 6.

Though important earth-movements in this area have apparently happened as late as the Pleistocene, they appear to have ceased before historic or even Palæolithic times. The sea-level cannot have been notably altered at Derna since the date of the Palæolithic camp at Bonmansur. I saw no recent raised beaches along the coast; and there are no distinct signs of recent subsidence. Stacey has referred to modern subsidences at Benghazi, while F. W. & H. W. Beechey have referred to indications of the recent advance of the sea seen during their surveys of the ancient Greek ports of Tokra, Ptolemeta, and Mersa Susa. The evidence even at these localities seems, however, to show that there has been no marked displacement of the shore-line since classical times. The sea has no doubt encroached at Benghazi and Mersa Susa,[1] but its advance at both places may be explained by ordinary coastal abrasion, with subsidences due to solution of limestone. The *Glycimeris* Limestones at Benghazi and Ptolemeta would suggest a slight emergence of the land, and not a subsidence; but they may have been storm-beaches and dunes subsequently separated from the sea by silting.[2]

The ancient wharf at Ptolemeta, according to the Beecheys' map, is now 150 yards from the shore-line, but the intervening beach is probably due to silting. At Mersa Susa there has been a slight encroachment of the sea near the ancient theatre; it has, on the other hand, receded at the old harbour, probably through silting, for the ruins of the ancient piers appear to stand at exactly their original level. The maps of Mersa Susa, Tokra and Ptolemeta, revised from the Admiralty Chart by Smith & Porcher,[3] show that there has been no serious change of sea-level since the building of those ancient towns by the Greek colonists, who began the colonization of Cyrenaica about 620 B.C.

VI. The Wadis, and Possible Variations in Pleistocene Climate.

The preceding evidence shows that Cyrenaica is a block of Eocene, Oligocene, and Miocene limestones, which was uplifted in Upper Miocene times (if the Gubah Limestones be Helvetian) and subsequently isolated by the foundering of the surrounding areas. The first subsidences in the Lower or Middle Pliocene formed the Tokra scarp and the Gulf of Syrtis, for the Cretaceous rocks—as at Tripoli—are separated from the sea only by Pleistocene deposits. The

---

[1] The most definite evidence of the advance of the sea is at Benghazi. G. B. Stacey writing in 1867 quoted Arab testimony that horse races had been held 50 years previously, inside the reef where the water was now 5 feet deep; and he states that the ruins of buildings were to be seen at low water on the reef: Q. J. G. S. vol. xxiii (1867) p. 384. The present brackishness of the wells at Mersa Susa has been regarded as evidence of encroachment of the sea or subsidence of the land by George Dennis, 'On Recent Excavations in the Greek Cemeteries of the Cyrenaica' Trans. R. Soc. Lit. ser. 2, vol. ix (1870) p. 144.

[2] That the shore has receded at Benghazi is remarked by F. B. Goddard, 'Researches in the Cyrenaica' Amer. Journ. Philology, vol. v, No. 17 (1884) p. 51.

[3] 'History of the Recent Discoveries at Cyrene' 1864, pl. i.

great tract of lowland, extending from Egypt to the south of Cyrenaica through the Oases of Siwa and Aujila, may have sunk at the same time, or it may not have been raised by the Miocene uplift to the same extent as Cyrenaica.

The maps of Cyrenaica, as for example that in Dr. Hildebrand's 'Cyrenaïka' pl. iii, represent the country as descending to the south in two steep steps; one of these steps is situated 25 miles south of Slonta; the other is much farther south, and it separates the Libyan Plateau from the lowland of the Wadi Fareg and the Oases of Siwa and Aujila, of which the former certainly and the latter probably are below sea-level. This representation suggests that the southern boundary of Cyrenaica consists of one or two faults, of which at least the southern is connected with the foundering of the Siwa-Aujila depression. The Slonta Arabs, however, assured us that the country passes gradually downwards into the Aujila plain; and if so, the Aujila district probably did not share the Miocene uplift, which increased gradually northwards.[1]

The predominant dip of the beds in Northern Cyrenaica is northward, and this direction continues as far south and west as the Wadi Khumas and Messa. In Central and Southern Cyrenaica the predominant dip is southward, and it is probably the same in South-eastern Cyrenaica. The main dip-slope, due to the Upper Miocene movements, was therefore to the south. The consequent rivers would, therefore, have carried whatever drainage there may have been down the southern slopes of Cyrenaica through the Wadi el Bah westwards to Benghazi, and through the Wadi el Ajara el Remla eastwards to the Bay of Bomba. Along the line of our traverse the most conspicuous drainage is to the north, although at Slonta and Silene we crossed streams beginning with a southward course, and the northern margin of the plateau has been notched by numerous gullies cut by obsequent streams. The wadis in Northern Cyrenaica are now deep cañons forming the most picturesque features in the scenery. Although some of the limestones, such as the typical rock of the Derna Limestone, are very soft, the cliffs of the wadis are sometimes vertical. These cañons, such as the wadi west of Mersa Susa (named by Smith & Porcher the Wadi Lebaiath, but my guide called it the Wadi Dimi-ell), the Wadi Jebrail, and the great Wadi Derna, are so large that they inevitably suggest the question, whether they were not excavated by great perennial rivers, when the country had a better water-supply and heavier rainfall than at present.[2]

---

[1] The evidence of the Arabs (see p. 586) agrees with the conclusion in Dr. Hildebrand's text, *op. cit.* pp. 151–152: 'We do not yet know how the whole Libyan plateau rises towards the north, whether it rises in terraces, whether it slopes up gently, or whether our Cyrenaica is placed on it like a dome. Only one thing almost all travellers have united in stating, that Cyrenaica gradually sinks to the south and at last loses itself in the Libyan Desert.'

[2] Corresponding to Dr. Blanckenhorn's 'Pluvial Period' in Egypt, 'Neues zur Geologie & Paläontologie Ægyptens—IV. Das Pliocän- & Quartärzeitalter' Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) p. 393 & table facing p. 308.

The occurrence of boulders 3 feet in diameter embedded in an old sheet of silt at the mouth of the Wadi Nagr, and of others lying on the bed of the wadi west of the Wadi Susa, shows that the floods have been of great power. Nevertheless, there does not seem to me any adequate evidence of a greater rainfall in Cyrenaica in historic times.[1] Northern Africa no doubt had a better rainfall than at present, at the time of the glaciation of parts of North-Western Europe: for the cyclonic systems, which now traverse Europe from west to east, would then have followed a more southern path. But that meteorological factor appears to have benefited Algeria and the Atlas Mountains rather than Cyrenaica, for even the older parts of the deep Cyrenaican wadis present the characteristics of cañons cut in an arid country. Nevertheless, it is probable that the wadis were cut at a time of heavier rainfall than at present, for very little excavation is now taking place in them. In some of the valleys, such as the Wadi Khumas north of Slonta, various facts show that there cannot have been any flow of water down the ravine for some years past. Thus plants of several years' growth stand on the lowest part of the channel; traces of cultivation, which must have been several seasons old, remain undisturbed on sheets of clay in depressions of the river-bed; footpaths have been worn clear of pebbles; and slight ridges of earth have gradually accumulated across the dry river-bed. Just above the lowest part of Wadi Khumas the valley contracts to a narrow gorge, which is filled with trees and shrubs, and I could see no flood-marks upon them. There can have been no heavy flood through this outlet for at least several decades. Below this point, however, a large tributary comes in from the north, from the neighbourhood of Messa; and the traces of recent movement of coarse gravel and the absence of shrubs from the river-bed, show that water had flowed across that river-bed within the last year or two. In the Wadi Jeraib some patches of rolled shingle with only young vegetation give evidence of some flow in a recent season; but the amount cannot have been considerable, for lower down the wadi the evidence of the flow had disappeared.

There is no evidence of any considerable deepening of these wadis in recent years. The largest cedars that we saw in Cyrenaica were in the Wadi Jeraib, where they are growing almost level with the river-bed, and chariot-tracks in the lowest part of the same wadi show that the bed has not been appreciably lowered since Roman times. Chariot-tracks worn in the limestone in other localities also show that the wadis have not been materially deepened since the Roman occupation. The gravel-platform at Bonmansur in the Wadi Derna may have been partly worn away since its occupation by Palæolithic man; but even there it is quite possible that no appreciable change has taken place since his time.

---

[1] The conditions of existing rainfall and water-supply are stated in the Expedition Report, pp. 5–6, 9–10, and in the Report by Mr. M. B. Duff, pp. 38–44. The most reliable rainfall records available, those at Benghazi from 1891 to 1894, are included in the table opposite p. 46.

There does not seem to be the slightest physiographic evidence of any considerable change in the rainfall or water-supply of Cyrenaica since the days of the Greek colonization in the seventh century B.C.; and the evidence furnished by the classical descriptions of the country, as also the waterworks erected by the Romans, indicates that the country was then under the same climatic conditions as at present.

J. P. Thrige, in his 'Res Cyrenensium' 1819 (2nd ed. 1828), has collected the classical records respecting Cyrenaica, and they indicate that the climate of the country was much the same in ancient as in modern times. There were probably more trees under the Romans, as they were then more carefully preserved; but the characteristic products of the province, such as wool, honey, wax, and corn, are indicative rather of moorlands with a limestone soil, than of a humid, wooded country. Plagues of locusts, insects characteristic of arid plains, devastated the land then as they do now: thus, in the year 125 B.C. they came in such swarms that accumulations of their bodies along the shore are said to have caused a pestilence. Other visitations are recorded, and they were so constant a danger that a law, quoted by Thrige (paragraph 80),

> 'made it obligatory for the people to wage an annual war against locusts, destroying first the eggs, then the brood, and ultimately those that had grown up, and imposed a penalty for negligence.'

The waterworks, which are the most conspicuous remains of the Roman occupation, also show that the country suffered from a scanty water-supply. Water was stored with great care, and Cyrene received a supplement of water from some artificial roofed reservoirs at Safsaf, about 6 miles distant in a straight line. The capacity of these reservoirs was measured by Dr. Trotter; the largest is about 960 feet long, 16 feet wide, and 12 feet deep; and the whole of them would have held about 1,500,000 gallons. If Cyrene had had a population of 15,000, the Safsaf reservoirs would have provided an allowance of only a gallon per head per day for three months. It would not have been worth while building a long stone aqueduct to carry so small a quantity, if a considerable supply had been available at Cyrene.[1]

Again, ancient Ptolemeta, according to Beechey,[2] had no springs, and was dependent for water upon an aqueduct: whereas, if there had been a reliable rainfall, wells in the ground behind the town would have yielded a considerable supply.

The ruins of ancient Greek and Roman buildings near all the

---

[1] It may be suggested that at the date of the first Greek colony the country had a wetter climate than at present, and that the Roman water-supply works mark the effort of the later colonists to maintain their hold over the country despite the increasing desiccation; but I can find no support for this suggestion, either in the classical literature, or in the physiography of the country.

[2] F. W. & H. W. Beechey, 'Proceedings of the Expedition to explore the Northern Coast of Africa, from Tripoly eastward' 1828, p. 361. See also R. M. Smith & E. A. Porcher, 'History of ... Discoveries at Cyrene' 1864, p. 66.

chief existing springs show that 2000 years ago those localities were the most important centres in the country, and that considerable springs were no more numerous than they are now. We saw no evidence that the springs had much larger volumes in classical times; and that the springs at Cyrene are as abundant as ever is asserted by the 'Mediterranean Pilot' (4th edit., vol. ii, 1905, p. 325). The country, moreover, in classical times suffered from famines following drought, as still happens occasionally, as just before the visit of Bruce to Benghazi in 1766.[1]

That the region to the south of Cyrenaica was arid in classical times is shown by the fact that Cyrenaica was the starting-point of caravan-routes to the Oases of Aujila and of Siwa, through which then, as now, passed one of the chief caravan-routes from Cyrenaica into Egypt. That these routes traversed a desert country is evident from the statement of Strabo,[2] according to whom, behind Cyrenaica and the Syrtis, is a very sterile and dry tract in the possession of the Libyans; and Aujila and Ammon (that is, Siwa) were then oases well supplied with water and productive of palm-trees. How little the geography of Cyrenaica has altered since the time of Strabo is shown by his statement that the country behind the coast produces trees for the width of 100 stadia,[3] and then for another 100 stadia the land is only sown, but from excessive heat does not grow rice. Hence, the tree-belt in Cyrenaica was then about 11½ miles wide, and to the south of it was a belt, also 11½ miles wide, of treeless plains producing dry cereals. The forests may have been thicker in classical times than they are now, but the forest-belt was apparently no wider.

That Cyrenaica in pre-classical times had a heavier rainfall seems to me probable from the aspect of some of the old valleys, which, from their curves and shape, I should suspect to have been carved during a period of greater rainfall; but this period, though doubtless Pleistocene, was probably pre-classical, and even earlier than the time of the people who made the stone implements which are scattered abundantly in several districts of Cyrenaica.

VII. The Composition of the Soils.

A series of analyses of the soil of Cyrenaica by Dr. J. Trotter is tabulated in the Report of the Expedition (pp. 28–36). As that report may not be easily accessible, some of the analyses are here reprinted. Nos. I–III illustrate the sedentary soils; nos. IV–XI the transported soils.

---

[1] R. L. Playfair, 'Travels in the Footsteps of Bruce in Algeria & Tunis' 1877, p. 285.

[2] 'The Geography of Strabo' translated by H. C. Hamilton & W. Falconer, vol. iii (1857) p. 294.

[3] The stadium, according to Smith's 'Dictionary of Greek & Roman Antiquities' (1845, p. 344) is 606 feet 9 inches English. 100 stadia = therefore about 11½ miles.

ANALYSES OF CYRENAICAN SOILS.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Organic matter, etc....	5·21	5·35	8·30	6·80	8·49	5·29	7·70	6·59	7·51	3·90	7·67
Iron oxide	4·15	6·79	4·58	5·72	6·91	16·88[2]	6·30	1·64	5·01	5·83	3·40
Alumina & soluble silica	8·45	14·11	7·21	5·62[1]	5·90[1]		5·98[1]	9·76	8·50	11·55	5·82
Lime	1·43	28·72	25·68	1·14	1·50	2·11	1·14	31·70	1·40	1·00	54·37
Magnesia	·05	·28	·04	·04	·51	·05	·31	·07	·09	·07	·09
Phosphoric anhydride	·14	·12	·16	·14	·13	·18	·19	·13	·11	·20	·79
Sulphuric anhydride.	·06	·04	·10	·07	·03	·03	·04	·04	·05	·05	·26
Potash	·63	·13	·14	·47	·23	·33	·28	·51	·83	·71	·34
Soda	·23	·49	·75	·70	·41	·68	·77	·63	·84	·58	1·91
Insoluble residue ...	79·65	43·97	53·04	79·30	75·89	74·45	77·29	48·93	75·66	76·11	25·35
Totals	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

I. A red loam from Gasr el Harib, plateau above Derna.
II. Above the Fountain of Apollo, Cyrene.
III. Near the Fountain of Apollo, Cyrene.
IV. Plain below the Fountain of Apollo.
V. Near the wells at Merj.
VI. North side of the Plain of Merj.
VII. South side of the Plain of Merj.
VIII. Ptolemeta.
IX. Plain of Silene.
X. Plain of Benghazi.
XI. Brown loam, from Derna.

---

[1] Alumina only.

[2] Iron oxide and alumina.

VIII. Summary of Conclusions.

Cyrenaica is a plateau of Eocene limestones ranging from the Lower to the Upper Eocene, and capped by limestones referred to the Aquitanian and the Miocene. The predominant dip is to the east, so that the Miocene limestones found on the plateau in Eastern Cyrenaica occur close to sea-level on the western coasts of Egypt. The Cyrenaican plateau may, therefore, be regarded as part of the western limb of the great syncline of Western Egypt.

The plateau has been isolated and fractured by a series of faults of late Kainozoic date. The position of the northern coast of Cyrenaica is determined by these faults, and the Tokra scarp separates the main plateau from the coastal plain east of Benghazi. The Tokra Fault is on the same line as an apparent fault in Western Crete.

The faults may be divided into three groups:—(1) those ranging east and west along the northern coast; (2) those trending from south-west to north-east, including the Tokra scarp and the parallel scarp which bounds the plain of Merj; and (3) the north-and-south faults which have determined some of the chief bends in the northern coast of Cyrenaica and Western Egypt. The three series are connected with the faults which have broken up the land of Ægea and formed the rift-valleys that have separated Eubœa from the mainland of Greece.

The rocks of Cyrenaica are limestones composed almost entirely of organic material. They contain occasional quartz-grains and some very fine clay. The limestones have been deposited in a clear sea, and usually in moderately deep water, though at the top of the Slonta Limestones there is a bank of coral-reef limestone. The limestones range from shallow-water deposits, down to those formed at a depth approaching 1000 fathoms.

The rocks may be classified as follows:—

Pleistocene	Alluvial deposits, etc.
Miocene	Gubah Limestones.
Oligocene	Cyrene Limestones.
Eocene.........................	Slonta Limestones. Derna Limestones. Apollonia Limestones.

The geological history of the country begins with the deposition of the chert-bearing Apollonia Limestones, which may be correlated with the Libyan or Lower Eocene Series of Egypt. The sea probably deepened to nearly 1000 fathoms, at which depth were deposited some chalky limestones with *Globigerina*. A re-elevation of the sea-bed led to the formation of limestone-breccias and conglomerates. Then followed another subsidence, during which were formed the cream-coloured limestones of Derna. This horizon is characterized by the typical form of *Nummulites gizehensis*.

art. Journ. Geol. Soc. Vol LXVII, Pl. XLII.

Fig 1.

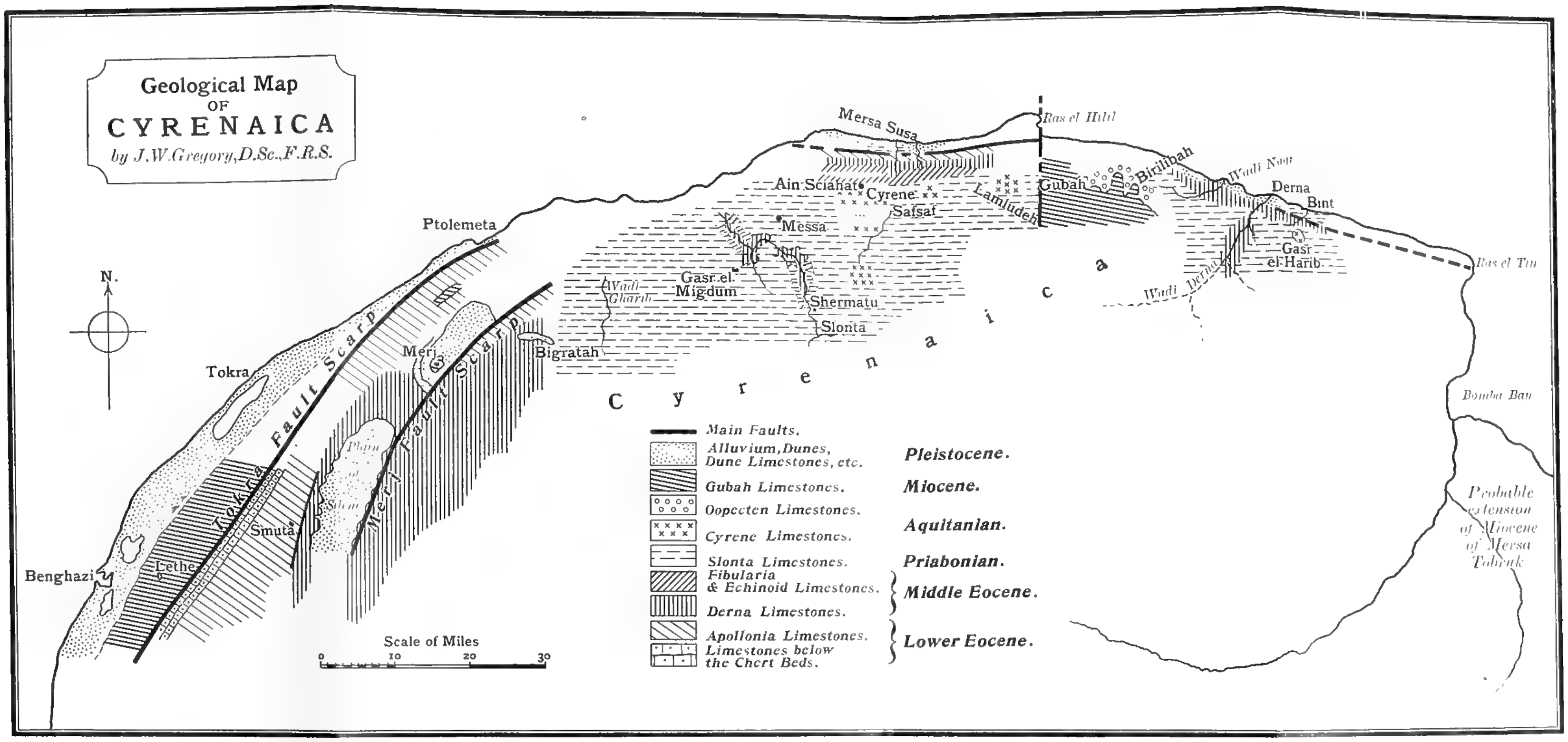
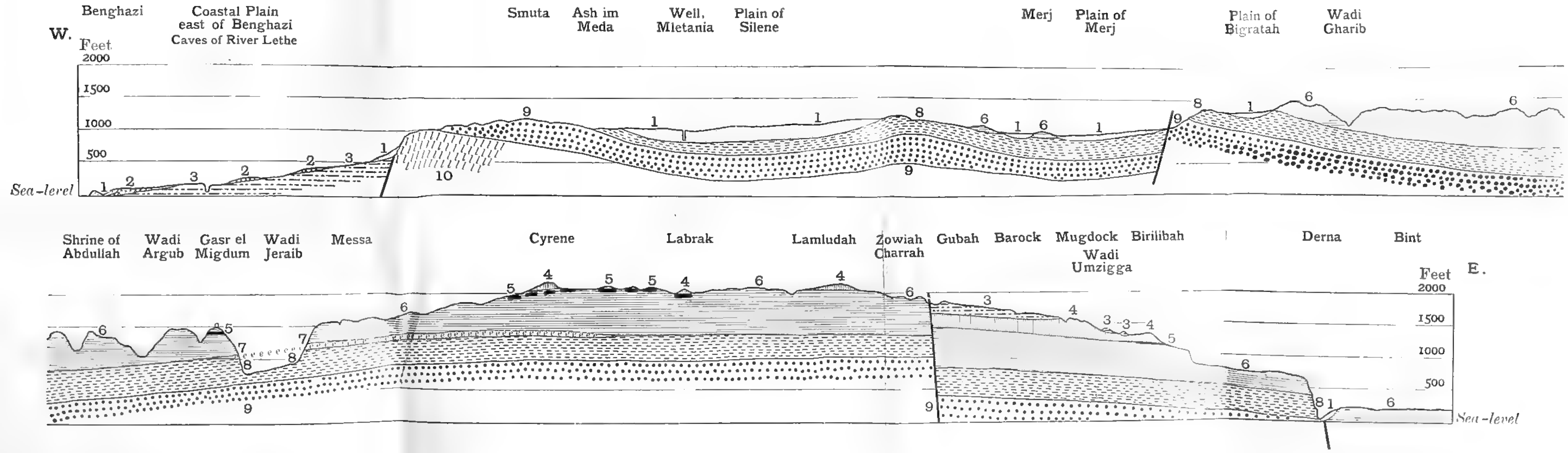
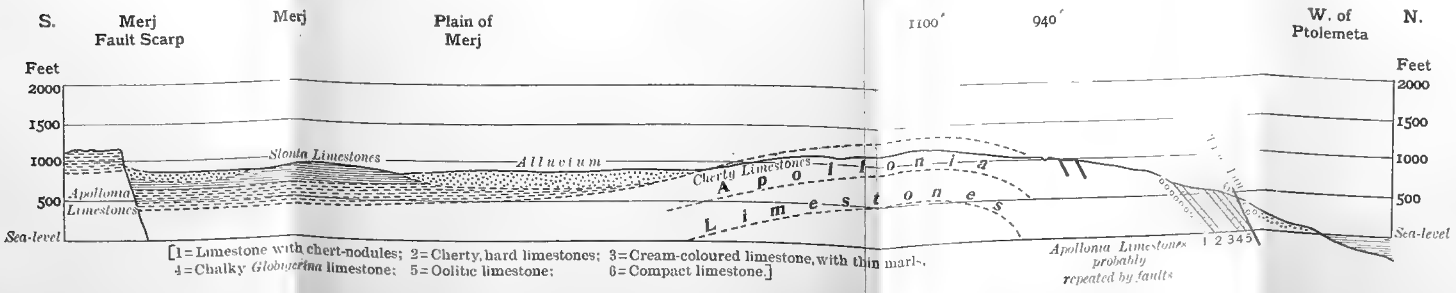


Fig. 2.—*Section from Benghazi to Derna: distance = about 170 miles.*



1 = Sand-dunes, dune limestones, alluvium, etc. } Pleistocene.
2 = *Cerastoderma-edule* limestone.
3 = Limestones of the Benghazi coast-plain and Gubah (Miocene, probably Helvetian).
4 = Cyrene Limestones (Aquitanian).
5 = Coral-reef limestones, near the top of the Slonta Limestones. } Priabonian.
6 = Slonta Limestones.
7 = Echinoid Limestones. } Mid-Eocene—Mokattam.
8 = Derna Limestones.
9 = Apollonia Limestones. } Lower Eocene—Libyan.
10 = Pre-Apollonia Limestones.

Fig. 3.—*Section from the Merj fault-scarp to the sea near Ptolemeta: distance = about 12 miles.*



[1 = Limestone with chert-nodules; 2 = Cherty, hard limestones; 3 = Cream-coloured limestone, with thin marls. 4 = Chalky *Globigerina* limestone; 5 = Oolitic limestone; 6 = Compact limestone.]

The Derna Limestone was succeeded by a marly limestone containing *Fibularia luciani*, followed by the deposition of a rough-weathering massive limestone containing many echinoid fragments. This rock was succeeded by the deposition of the stratified Slonta Limestones, which are represented near Cyrene by a soft cream-coloured nummulitic limestone containing *N. gizehensis*, var. *lyelli*. This rock appears to pass southwards into the harder brown-weathering Slonta Limestones, which were formed in shallower water. The Slonta Limestones contain Priabonian mollusca and an *Echinolampas* Bed, in which the common species is referred to *E. chericherensis* Gauth., of the Priabonian of Tunis. The deposition of the Slonta Limestones was brought to an end by a stratigraphical break, and the next series begins with a glauconitic marl containing many rolled limestone-fragments. This bed passes upwards into the yellow Cyrene Limestone, characterized by the abundance of *Operculina*. That limestone is referred, from the evidence of the molluscs and echinoids, to the Aquitanian. These beds are best developed above the Fountain of Apollo at Ain Sciahat, Cyrene.

Miocene rocks occur at Gubah, where they have been let down by faults, and along the coastal plain east of Benghazi, where they lie at the foot of the Tokra scarp. The country appears to have been uplifted after the Middle Miocene, and to have become part of a wide land which extended northwards and included Crete and the Ægean Sea.

The land was afterwards broken up by great subsidences, which left Cyrenaica as a horst, bounded by the fault-scarps on the north and west, isolated from Crete, and sinking slowly southwards to the Siwa-Aujila depression.

The river-valleys in Northern Cyrenaica belong to an obsequent system, the formation of which was probably started during a period when the rainfall was heavier than at present; but there appears to be no evidence of any appreciable change in the climate or water-supply of the country since the date of the Greek colonization, which began about 620 B.C.

EXPLANATION OF PLATE XLII.

Fig. 1. Geological map of Cyrenaica, on the scale of 20 miles to the inch, or 1:1,267,200.

2. Section from Benghazi to Derna.

3. Section from the Merj fault-scarp to the sea near Ptolemeta.

(B) KAINOZOIC MOLLUSCA *from* CYRENAICA.

By RICHARD BULLEN NEWTON, F.G.S.

[PLATES XLIII–XLVI.]

CONTENTS.

I. INTRODUCTION.

AMONG the geological specimens obtained from Cyrenaica by Prof. J. W. Gregory, during a journey through that province of Northern Africa in the summer of 1908, are a considerable number of molluscan remains, which it has been my privilege to study and report upon in the following notes. It may be at once mentioned that the more important part of this collection will be presented by Prof. Gregory to the Geological Department of the British Museum (Natural History).

Speaking generally, the shells are badly preserved, and some consist merely of internal casts; hence only one new species has been made, namely, *Æquipecten cyrenaicus*, referred to the Priabonian horizon—a more useful purpose, it is hoped, being served in the endeavour to show relationships to already described forms.

The specimens are, however, easily divisible into various groups of the Kainozoic System, none offering characters that would indicate their attribution to the Mesozoic or any older series of the sedimentary rocks.

The more ancient specimens are the most numerous and probably of greatest importance, since they denote such horizons as the Lutetian, Priabonian, Aquitanian, and Vindobonian: those of later age belonging both to the earlier and to the newer deposits of the post-Pliocene Epoch.

The rocks associated with the Lutetian and Priabonian fossils are full of nummulites and occasional specimens of *Orthophragmina*; while those that form the matrix of the Aquitanian and Vindobonian specimens exhibit foraminiferal organisms such as *Operculina*, *Amphistegina*, *Lepidocyclina*, etc., but no nummulites. This is interesting confirmation of what has been generally recognized, that nummulites ceased to exist when the Aquitanian Period had arrived, their place being taken by Lepidocycline forms of *Orbitoides*.[1]

So far as the literature of this subject is concerned, very little is

---

[1] A. de Lapparent, 'Traité de Géologie' 5th ed. (1906) p. 1586.

known of the palæontology of Cyrenaica, although the few references available suffice in a general way to indicate the geological relations existing between that country and contiguous regions of Northern Africa, Crete, and other portions of the Mediterranean area.

Some of the earliest remarks on this subject were made by Admiral T. A. B. Spratt, in his 'Travels & Researches in Crete' 1865 (vol. ii, p. 378), where he incidentally described the geological structure of Derna (Derneh) in Cyrenaica, reporting the occurrence of freshwater deposits, and of an older group of strata, more ancient than those of Malta, containing nummulitic tests such as are found in Crete. It was further mentioned, in the same work, that at Salum, to the east of Cyrenaica, '*Nautilus zigzaggia*' had been found—a form which he believed to be restricted to the London Clay, the Paris Basin, and the Maltese beds; yellowish limestones were also stated to occur above the nummulitic rocks at Derna, full of pectens, echinoids, etc. This account of the structure of Derna was embodied in the following section:—

1. Freshwater deposits (lacustrine—*Limnæa*).
2. Yellowish limestone (*Pecten*, etc.).
3. Nummulitic beds.

Two years later, G. B. Stacey, in his paper 'On the Geology of Benghazi,'[1] referred to fossils from that area as—three species of Echinodermata, two forms of *Ostrea*, a *Pecten*, two corals, 'a worm in the form of a *Helix*'; and on the surface *Cardium edule*. No particular age was assigned to any of these organisms, although it was recognized that the fundamental rock of the country was a Tertiary limestone.

The Archduke Ludwig Salvator, describing the Cave of Lethe, east of Benghazi, observed that its walls were formed of 'Nummulitenkalk.'[2]

An interesting specimen of *Nummulites*, now in the British Museum and formerly collected by Admiral Spratt, was referred to by the late Prof. T. Rupert Jones, in his 'Catalogue of Fossil Foraminifera in the British Museum (Natural History)' 1882, p. 45, as *Nummulites perforata* from Mersa Susa (an ancient port of Cyrene), and he remarked that it had been obtained 'from strata younger than the nummulitic bed of Crete.'[3]

Zittel, in the introduction to his great work on the Geology of the Libyan Desert, stated that

> 'In the neighbourhood of Siwah the coarse Miocene limestone is the latest marine sediment of the Libyan Desert. Probably it extends northwards over the Cyrenaican tableland.' (Palæontographica, vol. xxx (1883) p. cxxxi.)

---

[1] Q. J. G. S. vol. xxiii (1867) pp. 384–86.

[2] 'Yacht-Reise in den Syrten, 1873' Prague, 1874, p. 52.

[3] This Cretan deposit is regarded at the present day as of Lutetian or Middle Eocene age; see A. de Lapparent, 'Traité de Géologie' 5th ed. (1906) p. 1530.

Two years later, Prof. Suess,[1] on the strength of Zittel's statement, regarded the Miocene 'Grobkalk' of Western Egypt as belonging to the second Mediterranean Stage, and hence as of Vindobonian or Helvetian-Tortonian age.

In 1884 Dr. Schweinfurth[2] collected fossils at Mersa Tobruk (Marmarica), which he regarded as of Miocene age, including *Scutella*. Subsequently M. G. Rolland[3] briefly referred to the Miocene ('Molasse Marine') rocks in the neighbourhood of the Siwa Oasis of Egypt and their extension to the plateau of Cyrenaica. Such deposits, he stated, were, according to Fuchs, representative of an age between the first and second Mediterranean Stage, or the 'Sables de Grund' of the Vienna Basin (=Lower Helvetian or Uppermost Burdigalian).

Some years later, Schweinfurth's fossils from Mersa Tobruk, and others obtained in 1890 from Mersa Badia, were systematically examined by Dr. M. Blanckenhorn, and included as part of the Miocene fauna in his memoir, 'Neues zur Geologie & Paläontologie Ægyptens: III—Das Miocän.'[4]

Dr. G. Hildebrand, in his work 'Cyrenaïka als Gebiet künftiger Besiedelung' (Bonn, 1904) pp. 84–86, recognized Miocene rocks only in that country, and doubted the presence of Nummulitic deposits. Describing some rocks from Tripoli, Prof. Stanislas Meunier[5] mentioned that he had seen none from that country older than Lutetian: specimens supposedly of *Cardium* were found with analogies to those of the Calcaire Grossier of the Paris Basin, but another *Cardium* occurring in the Tertiary rocks of Cyrenaica was more recent than those from Tripoli.

Writing on the geology of Tripoli, Dr. L. Pervinquière[6] noted the occurrence of Cretaceous fossils in that country, as previously determined by Beyrich[7]; and a year later Dr. Lothar Krumbeck published figures and descriptions of Cretaceous fossils from the same country.[8] A brief general notice of the geology of Cyrenaica is given by Prof. J. W. Gregory[9] in an official account of his journey to that province, in which he rejects the inferences founded on statements by Della Cella concerning the discovery of ammonites in 1817, which suggested the presence of Mesozoic rocks in that area of Northern Africa.

---

[1] 'Das Antlitz der Erde' vol. i (1885) p. 470.

[2] Bull. Inst. Égyptien, ser. 2, No. 4 (1884) p. 82.

[3] 'Géologie du Sahara Algérien, etc.—Chemin de Fer Transsaharien' French Government Report [Paris] 1890, p. 86.

[4] Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) pp. 104 & 105.

[5] Bull. Soc. Géol. France, ser. 4, vol. v (1905) p. 69.

[6] *Ibid.* pp. 527–29.

[7] Monatsb. Verhandl. Ges. Erdkund. Berlin, vol. ix (1852) pp. 156–62.

[8] Palæontographica, vol. liii (1906) pp. 51–135, pls. vii–ix.

[9] 'Report on Work of Commission, Jewish Territorial Organization' 1909, p. 5.

II. POST-PLIOCENE.

The post-Pliocene mollusca are both marine and non-marine. Among the marine, which are the most numerous, are those found in marls and compact limestones obtained from west of Ptolemeta and the plain east of Benghazi, and considered to belong to an ancient series of the post-Pliocene Period. On the other hand, there is a series of shell-remains contained in a cream-coloured limestone made up of comminuted shells and minutely-formed calcareous pebbles, loosely, though closely, agglutinated together, occurring at Benghazi, which is apparently a recent beach-deposit and much younger than those limestones described as belonging to the older beds of this period. In this youngest series of deposits would be also included a few terrestrial shells, forming part of this collection, obtained from the plain east of Derna, and Bonmansur, south of Derna. The whole of the marine shells have been referred to Mediterranean or Atlantic species, the terrestrial representing forms now living in Mediterranean countries and chiefly those of Northern Africa.

The oldest post-Pliocene shells include chiefly *Cerastoderma edule*, which occurs in abundance to the east of Benghazi. Similar shells are known over the whole of Northern Africa and Mediterranean countries generally, and, when occurring in rocks fairly well removed from the sea-border, are recognized as belonging to the more ancient series of this period. M. Rolland has furnished a good account of the occurrence of this shell in Algerian localities.[1]

The non-Marine post-Pliocene (Recent Beds) Mollusca.

Gastropoda.

HYGROMIA SORDULENTA (Morelet). (Pl. XLIII, figs. 1 & 2.)

Helix sordulenta Morelet, Journ. Conchyl. [Paris] 1851, vol. ii, p. 356; Letourneux & Bourguignat, Explorat. Scient. Tunisie (Prod. Mal. Terr. Fluv.) 1887, p. 10.

Helicella (Fruticicola) sordulenta Tryon, 'Manual of Conchology' 1887, ser. 2, vol. iii, pl. xxxix, figs. 1 & 2, p. 177.

Hygromia (Fruticicola) sordulenta Pilsbry, Tryon's 'Manual of Conchology' 1894, ser. 2, vol. ix, p. 275.

Remarks.—This species was originally described from Constantine, in Algeria, and has since been recognized by Letourneux & Bourguignat from localities in Tunisia.

Occurrence.—Associated with a reddish-brown loamy material.

Locality.—Bonmansur, south of Derna.

---

[1] 'Géologie du Sahara Algérien—Chemin de Fer Transsaharien' French Government Report [Paris] 1890, pp. 158, 194, &c. & pl. xxviii, figs. 20–21.

HELICELLA TUBERCULOSA (Conrad). (Pl. XLIII, figs. 3–5.)

Caracolla tuberculosa Conrad, in W. F. Lynch's 'Official Report of the U.S. Exped. Dead Sea, &c.' 1852, pl. xxii, fig. 132 & p. 229.
Helix tuberculosa von Martens, Sitz-Ber. Gesellsch. Naturf. Freunde Berlin ('Landschnecken & Reptilien aus der Cyrenaïka') 1883, p. 147.
Helicella (Turricula) tuberculosa Tryon, 'Manual of Conchology' 1888, ser. 2, vol. iv, p. 25.

Remarks.—This species, which assumes roughly the characteristics of a *Trochus*, as indicated in the original description, is represented by beautifully preserved specimens of variable dimensions: the smallest having a length and basal width of 3 millimetres in both directions, the largest measuring 15 mm. in length and the same in width, which is an unusual size for the species. The shell was originally described from the Dead Sea region; von Martens has recorded it from Benghazi, in Cyrenaica, and Bourguignat from Southern Syria, near Jerusalem, and probably from Arabia Petræa.[1]

Occurrence.—In a reddish-brown sandy-looking soil.

Locality.—Plain east of Benghazi.

The Marine post-Pliocene (Recent Beds) Mollusca from the Beach-Deposits of Benghazi.

Gastropoda.

CERITHIUM cf. VULGATUM Bruguière.

Cerithium vulgatum Bruguière, Encycl. Méth. (Vers) 1792, vol. i, pt. 2, p. 481; Sacco, 'Moll. Terr. Terz. Piemonte' 1895, pt. 17, pl. i, figs. 15–34 & pp. 6–11 (and varieties); P. Bédé, Feuille des Jeunes Naturalistes, 1904, No. 408, p. 4.

Remarks.—Consists of a fragmentary worn specimen. Prof. Sacco regards certain varietal forms as ranging through the Miocene (Helvetian) and Pliocene rocks; while M. Paul Bédé has recognized the species in the more ancient Quaternary deposits of Tunisia (Sfax), and the mollusc thrives at the present day in southern European seas.

COLUMBELLA RUSTICA (Linnæus).

Voluta rustica Linnæus, 'Systema Naturæ' 1758, ed. 10, p. 731.
Colombella rustica Lamarck, 'Hist. Nat. Anim. sans Vert.' 1822, vol. vii, p. 293; Tryon, 'Manual of Conchology' 1883, vol. v, pl. xliii, figs. 34–49 & pl. xliv, figs. 50–56, p. 107; P. Bédé, Feuille des Jeunes Naturalistes, 1904, No. 408, p. 2.

Remarks. — An imperfect worn example referable to this species is in the collection. The shell does not appear to have been recognized by Prof. Sacco in the Italian Pliocene, but M. Paul Bédé records it from the more recent Quaternary beds of Tunisia (Sfax), and the form is well known as living in the Mediterranean and Atlantic.

---

[1] 'Moll. Nouv. Litigieux ou Peu Connus' 1863, pt. 1, pp. 60–63.

CHELYCONUS MEDITERRANEUS (Hwass, in Bruguière).

Conus mediterraneus Hwass, in Bruguière, 'Hist. Nat. des Vers: Moll.' Encycl. Méth. 1792, vol. i, pt. 2, p. 701, & *ibid.* 1798 (edited by Lamarck) pl. cccxxx, fig. 4.
Chelyconus mediterraneus (varieties) Sacco, 'Moll. Terr. Terz. Piemonte' 1893, pt. 13, pl. x, figs. 1–15 & pp. 103–107.
Conus mediterraneus Bédé, Bull. Mus. Hist. Nat. [Paris] 1903, vol. ix, pp. 422–25.

Remarks.—A single specimen has been determined as this species, but soon after identification it was unfortunately lost. Prof. Sacco has described varieties from the Upper Tertiary of Italy; while M. Paul Bédé records it from the post-Pliocene deposits of Tunisia (Sfax), and the species lives at the present day.

Pelecypoda.

OSTREA EDULIS Linnæus.

Ostrea edulis Linnæus, 'Systema Naturæ' 1758, ed. 10, p. 699; Sacco, 'Moll. Terr. Terz. Piemonte' 1897, pt. 23, pls. i–ii & pp. 4–9.

Remarks.—This form is represented by a single thick and roughly-worn valve, which partly discloses the ligamental area. According to Prof. Sacco, several varieties of this oyster occur throughout the Helvetian stage of the Miocene and also in the Pliocene rocks of Italy. It has also been recognized by various authors from the post-Pliocene deposits of Mediterranean countries, England, etc., Messrs. Bellamy & Jukes-Browne mentioning its occurrence in such beds at Cyprus.[1] The species belongs to the living fauna of the seas of Europe, etc.

GLYCYMERIS GLYCYMERIS (Linnæus).

Arca glycymeris Linnæus, 'Systema Naturæ' 1758, ed. 10, p. 695.
Pectunculus glycymeris Searles Wood (*pars*), Monogr. Pal. Soc. (British Crag Mollusca) 1850, pl. ix, figs. 1 *a*–1 *b* & p. 66.

Remarks.—This species is here restricted to the widely orbicular examples and not to the more elongate forms, which are regarded as belonging to the species *pilosa* of Linnæus, described in a later edition of the 'Systema Naturæ.' Its advent dates from Pliocene times, and it lives at the present day in European seas.

CERASTODERMA EDULE (Linnæus). (Pl. XLIII, fig. 6.)

Cardium edule Linnæus, 'Systema Naturæ' 1758, ed. 10, p. 681.
Cerastoderma edule Sacco, 'Moll. Terr. Terz. Piemonte' 1899, pt. 27, pl. xi, fig. 24 (and varieties, figs. 25–32) & pp. 48, 49.

Remarks.—This species and its varieties are regarded as commencing in Pliocene times; it is also now found in the seas of Europe. The collection contains two left valves from this deposit, which is regarded as being of more recent origin than those from the compact limestone to be presently mentioned. According to M. Paul Bédé,[2] the species occurs in both divisions of the Quaternary formations of Tunisia.

---

[1] 'Geology of Cyprus' 1905, p. 41.

[2] 'La Feuille des Jeunes Naturalistes' 1904, No. 408, pp. 2 & 13.

MACTRA STULTORUM (Linnæus).

Cardium stultorum Linnæus, 'Systema Naturæ' 1758, ed. 10, p. 681.
Mactra stultorum Linnæus, *ibid.* 1767, ed. 12, vol. i, pt. 2, p. 1126; Searles Wood, Monogr. Pal. Soc. (British Crag Mollusca) 1853, pl. xxiii, figs. 3*a*–3*d* & p. 242.

Remarks.—As well as being a well-known present-day species (European seas), this shell has been recognized by Searles Wood as British Pliocene, and by Prof. Sacco, under the Linnæan name of *Corallina*, from rocks of similar age in Italy. There is but a single left valve, embedded in matrix, to illustrate this form, showing external characters.

JAGONIA PECTEN (Lamarck). (Pl. XLIII, figs. 7 & 8.)

Tellina reticulata Poli, 'Testacea Utriusque Siciliæ' 1795, vol. ii, 2nd Order (Bivalvia) pl. xx, fig. 14, p. 48 (? *non* Linnæus).
Lucina pecten Lamarck, 'Hist. Nat. Anim. sans Vert.' 1818, vol. v, p. 543.
Jagonia reticulata Sacco, 'Moll. Terr. Terz. Piemonte' 1901, pt. 29, pl. xx, figs. 65–67 & p. 97; Bédé, Feuille des Jeunes Naturalistes, 1904, No. 408, p. 3.

Remarks.—This species, which forms the type of Recluz's genus *Jagonia*,[1] is regarded as ranging from the Tortonian stage of the Miocene and through the Pliocene (see Sacco); M. Paul Bédé also recognizes it as occurring in the recent Quaternary deposits of Tunisia (Sfax). It also lives in the Mediterranean. Only one valve is in the collection.

LORIPES LACTEUS (Linnæus).

Tellina lactea Linnæus, 'Systema Naturæ' 1758, ed. 10, p. 676.
Lucina leucoma Turton, 'Conchylia Insularum Britannicarum' 1822, p. 113, pl. vii, fig. 8.
Loripes lacteus Sacco, 'Moll. Terr. Terz. Piemonte' 1901, pt. 29, pl. xxix, figs. 1–4 & p. 98; P. Bédé, Bull. Mus. Hist. Nat. [Paris] 1903, vol. ix, p. 422.

Remarks.—The species is common to Miocene (Tortonian) and Pliocene rocks, and is a member of the recent fauna (Mediterranean). M. Paul Bédé schedules it among the recent Quaternary fauna of Tunisia (Sfax).

The Marine post-Pliocene (Ancient Beds) Mollusca.

Pelecypoda.

GLYCYMERIS PILOSA (Linnæus).

Arca pilosa Linnæus, 'Systema Naturæ' 1767, ed. 12, vol. i, pt. 2, p. 1143.
Pectunculus glycymeris, Searles Wood, Monogr. Pal. Soc. 1850, pl. ix, fig. 1 *d* & p. 66; and Monogr. Pal. Soc. 1874 (Supplement), vars. *inflatus* & *insubricus* Brocchi, p. 116.
Axinea pilosa Sacco, 'Moll. Terr. Terz. Piemonte' 1898, pt. 26, pl. vii, figs. 4–7 & p. 31.

Remarks.—This specimen consists of a left valve showing somewhat eroded external characters, the umbonal and hinge-regions being also seen; otherwise, the interior is filled with matrix. The surface-striations, both longitudinal and concentric, present the decussated sculpture of this species. Most authors have united *Gl. pilosa* with *Gl. glycymeris*, an earlier described shell of

---

[1] Actes Soc. Linn. Bordeaux, 1869, vol. xxvii, pp. 35–41.

Linnæus, both found living in the Mediterranean. Deshayes, however, has pointed out (on the authority of Hanley, 'Ipsa Linnæi Conchylia' 1855, pp. 99 & 100) that in *Glycymeris glycymeris* the concentric striations are more obvious and the valves generally more depressed. In addition, it would appear that the contour of *Gl. pilosa* is more or less elongate, whereas in the other species it is usually much rounder.

Dimensions (left valve).—Length = 48 millimetres; height = 52 mm.; diameter = 20 mm.

Prof. Sacco has recorded this shell from the Tertiary deposits of Italy, regarding its range as extending from Helvetian times. It occurs in the Pliocene (Coralline Crag) of England, where Searles Wood has recognized it under *Pectunculus glycymeris*, showing varietal characters of *P. inflatus* and *P. insubricus* of Brocchi.

Occurrence.—The matrix is a cream-coloured limestone, coated with a thick brick-red rock which is also of calcareous composition.

Locality.—West of Ptolemeta.

CERASTODERMA EDULE (Linnæus). (Pl. XLIII, figs. 9 & 10.)

[Additional synonymy to that on p. 621.]

Cardium crassum Defrance, Dict. Sci. Nat. [Paris] 1817, vol. v, Suppl. p. 106, *non* Gmelin; Philippi, 'Enumeratio Molluscorum Siciliæ' 1836, pl. iv, fig. 17 & p. 53.

Cardium rusticum Eichwald, 'Fauna Caspio-Caucasia' 1841, pl. xxxviii, figs. 26–27 & p. 215, *non* Linnæus.

Cardium edule [pars], *umbonatum*, etc., Searles V. Wood, Monogr. Pal. Soc. (British Crag Mollusca) 1853, pl. xiv, figs. 2*a*–2*g* & p. 155.

Remarks.—This species exhibits many variations, but, speaking generally, the examples of the present collection appear to favour a form figured by Searles Wood from the English Crag, called *C. edule* var. *umbonatum*, which has produced and inflated umbones as well as thick and well-defined costæ; it is the same as Eichwald's *C. rusticum*, which lives in the brackish waters of the Aralo-Caspian region of Europe, being also found fossil in the shore-deposits of that district. The specimens likewise resemble a fossil from Sicily described and figured by Philippi as *Cardium crassum*, which, so far as the figure is concerned, shares all the characters of the forms from Cyrenaica. The costæ are subangulate and ornamented at first with extremely fine concentric striations which have the appearance of delicate annulations, these afterwards giving place to a coarser condition of annulated structure, the segments of which become so thick that they resemble nodosities. All the valves are of thick and robust character.

Dimensions (large example with united valves).—Length = 40 millimetres; height = 30 mm.; diameter = 28 mm.

Specimens of this shell are numerous. The species is known from other areas of Northern Africa, and likewise from most countries skirting the Mediterranean Sea, in rocks of similar age; Prof. Sacco and Searles Wood, however, have recognized it in the Pliocene of Italy and England, and it is besides known as a living

Mediterranean and Atlantic species. In post-Pilocene deposits it has been recognized by d'Archiac from Greece,[1] by P. Fischer from Asia Minor,[2] by M. G. Rolland from localities in Algeria,[3] by Dr. Blanckenhorn in the neighbourhood of Alexandria,[4] by M. Bédé from Tunisia (Sfax),[5] by Messrs. Bellamy & Jukes-Browne from Cyprus,[6] and by Dr. Pachundaki from near Mersa Matruh on the Marmarican plateau of Northern Africa.[7]

Occurrence.—The shells are associated with a compact cream-coloured limestone, and sometimes with a soft, pale, marly-looking rock; an external tinge of reddish brown, the result of weathering, etc., is observed on most of the specimens. The small brackish-water gastropod *Paludestrina* (=*Hydrobia*) occurs in the same matrix with these specimens.[8]

Locality.—Plain east of Benghazi.

---

[1] In Viquesnel's 'Voy. Turquie d'Europe' 1855, vol. ii, pl. xxiv, fig. 7 & p. 479.

[2] In P. de Tchihatcheff's 'Asie Mineure' pt. iv (1866-69) p. 356.

[3] 'Géologie du Sahara Algérien—Chemin de Fer Transsaharien' French Government Report [Paris] 1890, pl. xxviii, figs. 20-21 & pp. 158, 194, etc.: both solid and fragile examples.

[4] 'Neues zur Geologie & Paläontologie Ægyptens—IV. Das Pliocän- & Quartärzeitalter' Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) p. 466.

[5] Bull. Mus. Hist. Nat. [Paris] vol. ix (1903) p. 423.

[6] 'The Geology of Cyprus' 1905, p. 51.

[7] 'Contrib. Géol. Marsa Matrouh (Marmarique)' 1907, pp. 4 & 6.

[8] [Since the reading of this paper, a re-examination has been made of the limestones containing *Cerastoderma edule* which Prof. Gregory obtained from 'Plain east of Benghazi.' They exhibit a number of small gastropods and fragmentary pelecypods which are of importance to include in this account of the fossil shells of Cyrenaica. The most frequently occurring genus is *Paludestrina*; there are also a Bulimuloid shell, another resembling a Helicoid, a possible *Truncatella*, *Nassa (?)*, fragmentary *Cerithium* like *vulgatum*, and some imperfect valves of probably Telliniform shells. Such a fauna would suggest a brackish-water origin, the deposition of the beds containing the same being due to lagoon or estuarine agencies rather than to conditions involving true marine characters.

Bourguignat ('Pal. Moll. Terr. Fluv. Algérie' [Paris] 1862, plates & text) has described a somewhat similar association of forms from the post-Pliocene formation of Algeria (the 'Chotts' of the Algerian Sahara); while Tournouer (C. R. Assoc. Franç. Av. Sci. 1879, Sess. vii, pp. 608-22, pl. vi), who subsequently studied the same area, was of opinion that the molluscan evidence was against the existence of a marine submergence of that part of Northern Africa during post-Pliocene times. There is another well-known instance of the occurrence of *Paludestrina* with *Cerastoderma edule* presented by the Aralo-Caspian region of Western Asia, where these molluscs are found both in the fossil and in the recent state. An interesting monograph has been published by Mr. W. Bateson on variations observable in the valves of *Cerastoderma edule* (Phil. Trans. Roy. Soc. London, 1890, vol. clxxx, pp. 297-330 & pl. xxvi), which he regards as due to differences of environment more particularly connected with the varied degrees of the salinity of the waters; the material for this work was collected by the author from the lake-regions of Northern Egypt (Mareotis, etc.), as well as from the Aralo-Caspian country.

The limestones from 'Plain east of Benghazi' appear, therefore, to represent two horizons: the oldest being Vindobonian and entirely marine, with *Scutella*, *Pecten ziziniæ*, foraminifera, and *Lithothamnion*; the youngest showing brackish-water characters from the presence of *Cerastoderma edule*, *Paludestrina*, etc., which are recognized as belonging to an ancient part of the post-Pliocene formation.]

CARDIUM TUBERCULATUM Linnæus.

Cardium tuberculatum Linnæus, 'Systema Naturæ' 1758, ed. 10, p. 679; Sacco, 'Moll. Terr. Terz. Piemonte' 1899, pt. 27, pl. ix, figs. 16–17 & p. 40; Bédé, Feuille des Jeunes Naturalistes, 1904, No. 408, p. 5.

Remarks.—Two fragmentary left valves represent this species, showing twenty costæ with somewhat eroded summits, yet preserving in places close and equidistant annulations or nodosities which are more delicate on the face of the shell but larger and swollen on the anterior surface. Close, squamulose, transverse striations decorate the remote intercostal grooves. The posterior side is deep and obliquely truncated.

Dimensions (approximate: largest left valve).—Length = 55 millimetres; height = 65 mm.; diameter = 30 mm.

The species is a well-known Mediterranean form. It also occurs in the Pliocene rocks of Italy, as described by Prof. Sacco and a number of previous authors, and M. Paul Bédé records it from the ancient Quaternary deposits of Tunisia (Sfax). This species would include *Cardium rusticum* of Linnæus, a fact acknowledged by most conchologists.

Occurrence.—The matrix associated with these specimens is a hard siliceous limestone, containing in abundance minute pebbly fragments of a white material; otherwise, the rock is brick-red in colour.

Locality.—West of Ptolemeta.

III. HELVETIAN-TORTONIAN.

The Helvetian-Tortonian (= Vindobonian of Depéret) rocks are particularly well known in various regions of Northern Africa, having been described by Zittel, Fuchs, the officers of the Geological Survey of Egypt, Dr. Blanckenhorn, and many other authorities for Egypt, including Dr. Pachundaki, the last-named in connexion with the structure of the Marmarican plateau to the west of Alexandria. The same beds are widely distributed over Mediterranean countries; and the few fossils from Cyrenaica now described are fairly well represented in the European development of this part of the Miocene System. Accompanying the shell-remains from Gubah are some fragmentary *Balanus* with probable affinities to *B. concavus* of Bronn, a related form of this species having been recognized by Fuchs in the Helvetian deposits of Geneffe (Egypt).

The other localities recognized as yielding fossils of this age in Cyrenaica are the Grotto, Lethe 'River,' near Benghazi; the plain east of Benghazi (which yields a limestone full of *Lithothamnion* and *Amphistegina*, etc.); and the tract extending from Merj Plain to Wadi Hamema.

Gastropoda.

Strombus cf. coronatus Defrance. (Pl. XLIII, fig. 14.)

Strombus coronatus Defrance, Dict. Sci. Nat. [Paris] 1827, vol. li, p. 124 Hœrnes, 'Foss. Moll. Tert.-Beck. Wien' 1852, pts. 2–4, pl. xvii, fig. 1 & p. 187; Sacco, 'Moll. Terr. Terz. Piemonte' 1893, pt. 14, pl. i, fig. 19 & p. 7.

Remarks.—Two limestone casts represent a form of *Strombus* allied to the *coronatus* of Defrance, the true species being known under different names (see Hœrnes and Sacco for the synonymy) having been described from France, Poland, Italy, Austria (Vienna Basin, etc.), the Morean region of Greece, etc., besides a related form determined by Fuchs from the Pyramids district of Egypt. Its range in time is regarded by Prof. Sacco as extending from the Tortonian division of the Miocene to the Astian Group of the Pliocene System. The specimens are of moderate size, exhibiting a widely spiral region with three or four tabulate whorls separated by a canaliculate suture; the aperture is elongate and narrow, while the columella terminates with a long and prominent excavation. The surface shows some very obscure concentric striations just below the summit margin of the body-whorl, and there are indications besides of distant nodulations on the same margin, from which extend obliquely some obscure growth-lines. This form is considered to be in closer relationship to *Strombus coronatus* than to *Str. bonelli* of Brongniart, on account of the great width of the summit-region, the latter species being relatively longer and more slender in its general contour.

Dimensions.—Length = 85 mm.; width (frontal) = 62 mm.

Occurrence.—The specimens are associated with a cream-coloured compact limestone, which has weathered reddish-brown, and is apparently full of foraminifera (*Amphistegina?*, etc.).

Locality.—Gubah.

Pelecypoda.

Alectryonia cf. plicatula (Gmelin). (Pl. XLIII, fig. 11.)

Ostrea plicatula Gmelin in Linnæus, 'Systema Naturæ,' 1790, ed. 13, vol. i, pt. 6, p. 3336.

Alectryonia plicatula Sacco, 'Moll. Terr. Terz. Piemonte,' 1897, pt. 23, p. 19.

Remarks.—I am inclined to place here a single lower valve attached to matrix, of an ostreiform shell showing external characters only. It is of rounded contour dorsally, posteriorly, and ventrally, but truncated and obliquely margined in the anterior area; the surface is generally depressed, its chief convexity being in the posterior region; the ornamentation consists of a series of five or six radial plications equidistantly separated, which bifurcate about midway and terminate in rounded tubular extremities.

Dimensions (lower valve).—Length = 50 mm.; height = 47 mm.; diameter = 15 mm.

The specimen compares favourably with *O. plicatula* of Gmelin, a recent Mediterranean species which has both its valves plicated,

and is hence regarded as an *Alectryonia*. According to Prof. Sacco, *A. plicatula* and its varieties range from Helvetian to the Astian division of the Pliocene in Italy, etc.

Occurrence.—In a light yellowish cream-coloured limestone, associated with *Operculina* and *Balanus* cf. *concavus* Bronn.

Locality.—Gubah.

ALECTRYONIA cf. VIRLETI (Deshayes).

Ostrea virleti Deshayes, 'Expéd. Sci. Morée' 1833, vol. iii, pt. 1 (Mollusques) pl. xxi, figs. 1–6 & pp. 122–24 (=*pseudoedulis* and *excavata* Deshayes); Fuchs, Denkschr. K. Akad. Wissensch. Wien, 1879, vol. xli, pt. 2, pl. iv, figs. 1–9 & p. 106; Palæontographica, 1883, vol. xxx, pls. ix–x [iv–v] & p. 43 [61].
Alectryonia virleti R. B. Newton, Geol. Mag. 1899, p. 205.

Remarks.—Scattered through a limestone are some fragments of an ostreiform shell, which show a regular and prominently plicated ventral region producing widely flexuous margins, and resembling most strongly what is present in examples of *O. virleti*, a species characteristic of Helvetian-Tortonian times, besides extending to the Pliocene, and is found in most Mediterranean regions, such as the Morea, Russian Armenia, Persia, Egypt, etc. It has quite recently been recognized in the base of the Helvetian Series, near Mersa Matruh (Marmarica), west of Alexandria, by M. G. F. Dollfus.[1]

Occurrence.—The matrix is a cream-coloured limestone, weathering reddish-brown. From a microscopical examination, it is found to be largely composed of *Orbitoides*, *Amphistegina*, and *Lithothamnion*, and may therefore be regarded as of Helvetian age. Such evidence, however, is against the views of the Archduke Ludwig Salvator, that author having recognized the rock as of Nummulitic age, a statement which makes it possible that the *Amphisteginæ* were formerly included under the more general term of *Nummulites.*

Locality.—The Grotto, Lethe 'River,' near Benghazi.

PECTEN ZIZINIÆ Blanckenhorn.

Pecten tournali Fuchs, Denkschr. K. Akad. Wissensch. Wien, 1878, vol. xxxviii, pt. 2, p. 37, *non* Serres.
Pecten solarium Fuchs, Palæontographica, 1883, vol. xxx, pp. 33, 40, & 57, *non* Lamarck.
Pecten solarium, var. *ægyptiacus* Blanckenhorn, Centralblatt Mineral. &c. [Stuttgart] 1900, p. 212.
Pecten ziziniæ, Blanckenhorn, Zeitschr. Deutsch. Geol. Gesellsch. 1901, vol. liii, p. 123, and Neues Jahrb. 1903, Beil.-Band xvii, pls. xiii–xiv & p. 167; Depéret & Roman, Mém. Soc. Géol. France, 1905, vol. xiii, pt. 2, No. 26, pl. ix, figs. 3–5 & p. 80.

Remarks.—Only the upper valve of this shell is preserved; although of imperfect condition and attached to a solid limestone-matrix, it has all the essential features of the species as originally described by Dr. Blanckenhorn and further remarked upon and figured by MM. Depéret & Roman. It seems to possess the dorso-median gibbosity which is characteristic of the species; otherwise, the valve is depressed.

Dimensions.—Length = about 80 mm.; height = about 70 mm.

---

[1] In D. E. Pachundaki's 'Contrib. Étude Géol. Marsa Matrouh' 1907, p. 35.

This species is essentially Egyptian, having been found in the rocks at Siwa, Gebel Geneffe, Wadi Haggu, etc., and near Sinai. A related form occurs in the Lower Helvetian beds of the Marmarican plateau near Alexandria, which has been recorded as *Pecten (Macrochlamys)* cf. *ziziniæ* of Blanckenhorn.[1]

Occurrence.—The matrix consists of a cream-coloured limestone, within a thick rim of compact reddish-brown limestone; a microscopical section shows foraminifera and algæ—such as *Operculina*, numerous specimens of *Amphistegina*, and *Lithothamnion*.

Localities.—Dr. Blanckenhorn mentions this species as occurring also at Mersa Badia and Mersa Tobruk. The present specimen was found on the plain east of Benghazi.

ANADARA cf. TURONICA (Dujardin). (Pl. XLIII, figs. 12 & 13.)

Arca turonica Dujardin, 'Les Couches du Sol en Touraine' Mém. Soc. Géol. France, 1837, vol. ii, pl. xviii, fig. 16 & p. 267; Hœrnes, 'Foss. Moll. Tert.-Beck. Wien' 1864, pl. xliv, fig. 2 & p. 332.

Anadara turonica Sacco, 'Moll. Terr. Terz. Piemonte' 1898, pt. 26, pl. v, fig. 14 & p. 24.

Remarks.—The specimens herewith determined consist of internal casts and impressions in a sandstone. Apparently the costæ vary numerically in the true *A. turonica*, as, according to Dujardin, from twenty-six to twenty-eight are seen in examples from France, whereas Vienna-Basin specimens, according to Hœrnes, possess thirty-five. The forms from Cyrenaica have a still greater number; and, although this is difficult to estimate exactly, it is probable that they possessed between forty and fifty ribs, which are consequently finer and much more microscopical in details of structure. These costæ, however, possess the usual minutely nodulated summits of this species, as well as the delicately transverse striations decorating the intercostal grooves. In general contour, also, the present specimens agree quite well with this species. Prof. Sacco regards it as of Helvetian age, and previously Theodor Fuchs had determined *Arca* cf. *turonica* from the Miocene deposits of Siwa in Egypt.[2]

Dimensions.—Length = 25 mm.; height = 15 mm.

Occurrence.—These casts and impressions are found in a fine cream-coloured sandstone, weathering reddish brown.

Locality.—Found on the traverse from Merj Plain to Wadi Hamema.

IV. AQUITANIAN.

Included in the Aquitanian Series are certain marine Pelecypoda which show a relationship to the 'Schioschichten' fauna of Northern Italy. They consist largely of pectinoid shell-remains furnished with costal systems of highly ornamental designs, which were obtained chiefly from the Ain-Sciahat area of Cyrenaica—the rocks of

---

[1] See D. E. Pachundaki, 'Contrib. Étude Géol. Marsa Matrouh (Marmarique)' Revue Internationale d'Égypte, vol. iv, pt ii (1907) p. 12.

[2] Palæontographica, vol. xxx (1883) p. 33.

that region being mostly grey, sandy-looking limestones containing well-preserved forms of *Operculina*. Further pectinoid shells collected at Wadi Umzigga and Birlibah, and exhibiting a much simpler costal structure, are associated with a matrix varying from a compact cream-coloured limestone to a yellowish arenaceous rock with minute blackish mineral grains and externally weathering to a light reddish-brown, which has yielded examples of *Lepidocyclina elephantina* Munier-Chalmas,[1] together with other orbitoidal organisms and *Operculina*. In none of these rocks mentioned as Aquitanian has the true *Nummulites* been observed.

Aquitanian deposits have not been recognized by Dr. Blanckenhorn as occurring in Egypt,[2] the lowest Miocene determined being the Langhian or Burdigalian stage, which is developed in the Moghara district of the Libyan Desert. A similar statement would probably apply to the other divisions of Northern Africa, although in Eastern Africa and Madagascar, according to A. de Lapparent's manual,[3] Aquitanian beds occur with *Lepidocyclina* and *Lithothamnion*. As stated previously, some of the species recorded here as Aquitanian resemble the 'Schioschichten' fauna of Northern Italy, but there are others which exhibit a facies belonging more to the Burdigalian or Helvetian type, such as *Æquipecten zitteli*, *Æ. camaretensis*, and *Æ. scabrellus*, and yet occurring in matrix similar to that associated with *Pecten vezzanensis*, *Æquipecten* cf. *pasinii*, and *Spondylus cisalpinus*. This mixture of forms is interesting although not unknown, as Dr. Oppenheim's memoir on the 'Schioschichten' refers to some pelecypods which are more usually recognized as Burdigalian or Lower Helvetian, rather than Aquitanian.[4]

Pelecypoda.

OSTREA cf. CAUDATA Münster. (Pl. XLIV, fig. 1.)

Ostrea caudata Münster in Goldfuss, 'Petrefacta Germaniæ' 1833, vol. ii, pl. lxxvii, figs. 7 *a*–7 *d* & p. 17.

Remarks.—The specimen thought to be related to this species is a lower valve, the exterior of which is in a very worn condition. It is of deltoid contour, very convex, and with a well-rounded posterior border; the anterior side is elevated, more or less abrupt, distinctly truncated near the ventral corner, and possessing an attachment cavity which occupies more than half the area of the shell. The surface exhibits a lamellar structure which appears to be crossed at distant intervals by very obscure radial plications. The interior is filled with matrix.

Dimensions (lower valve).—Length = 48 millimetres; height = 50 mm.; depth = 20 mm.

---

[1] See Mr. Chapman's paper on the Foraminifera of this collection (p. 660).

[2] Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) pp. 52, etc.

[3] 'Traité de Géologie' 5th ed. (1906) p. 1597.

[4] Zeitschr. Deutsch. Geol. Gesellsch. vol. lv (1903) pls. viii–xi & pp. 98–235.

The true *O. caudata* belongs to the Miocene regions of Germany (Goldfuss, etc.), Egypt (Oasis of Siwa) as recorded by Dr. Blanckenhorn,[1] and of the Marmarican plateau near Alexandria as recognized by M. G. F. Dollfus,[2] and is regarded as of Lower Helvetian age.

Occurrence.—Matrix of a reddish-brown colour and full of foraminifera (*Operculina*, etc.).

Locality.—East of the shrine of Sidi Mahomet Mahridi, east of Slonta.

OSTREA CRASSICOSTATA G. B. Sowerby. (Pl. XLV, figs. 1 & 2.)

Ostrea crassicostata G. B. Sowerby, Q. J. G. S. 1847, vol. iii, pl. xix, fig. 23 & p. 420; Hœrnes, 'Foss. Moll. Tert.-Beck. Wien' 1870, pl. lxviii, fig. 4, p. 441; F. A. P. da Costa, 'Moll. Tert. Portugal' Comm. Serv. Géol. Portugal, 1903, p. 5.

Ostrea excavata Oppenheim, Zeitschr. Deutsch. Geol. Gesellsch. 1903, vol. lv, pp. 151–52.

Remarks.—The best of two specimens is a fine example of Sowerby's shell originally described from Portuguese Tertiary beds, now regarded as of Lower Burdigalian age.[3] Only the lower valve is preserved, but it is exceedingly thick and robust, exhibiting on the dorsal surface the nearly equidistant and few longitudinal plications so characteristic of the species. The interior possesses a moderately excavated area, a deeply impressed anterior muscular scar of large size with a concentrically banded surface, and a short and broad ligamental area.

Dimensions.—Length = 75 millimetres; height = 90 mm.; thickness = 50 mm.

According to Hœrnes the species ranges from the lower beds of the Horner Schichten (=Aquitanian) to the Leithalkalk (=Tortonian) of Vienna Basin localities; and, as previously stated, it belongs to the Lower Burdigalian deposits of Portugal and the Aquitanian of Italy.

Occurrence.—Next to no matrix is associated with these specimens, and both have a generally reddish-brown colour; no foraminifera are discernible.

Localties.—East of the shrine of Sidi Mahomet Mahridi, east of Slonta. The thick example comes from west of Lamludeh.

SPONDYLUS CISALPINUS Brongniart. (Pl. XLIV, fig. 2.)

Spondylus cisalpinus A. Brongniart, 'Mém. Terr. Séd. Supér. Calcaréo-Trapp. du Vicentin' 1823, pl. v, figs. 1*a*–1*c* & p. 76; Fuchs, 'Beitr. Conchyl. Vicentinischen Tertiärgeb.' Denkschr. K. Akad. Wissensch. Wien, 1870, vol. xxx, pt. 2, pl. vii, figs. 11–12 & p. 168; Hœrnes, 'Beitr. z. Kenntn. Tert Ablag. Südalpen (Schioschichten)' Jahrb. K.K. Geol. Reichsanst. 1878, vol. xxviii, p. 29; Oppenheim, Palæontographica, 1901, vol. xlvii, p. 141, and Zeitschr. Deutsch. Geol. Gesellsch. 1903, vol. lv, p. 175.

Remarks.—A single example with both valves in the closed condition represents this species. It is quite a limestone specimen

---

[1] Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) p. 109.

[2] In D. E. Pachundaki's 'Contrib. Étude Géol. Marsa Matrouh (Marmarique)' Revue Internat. Égypte, vol. iv, pt. ii (1907) p. 12.

[3] See F. A. P. da Costa, *op. cit.* pp. 3 *et seqq.*

with no actual shell remaining; and the surface has evidently been subjected to some erosive action, as the costal system is very depressed and in places obscure. The umbonal region is not preserved. Both the valves are of nearly equal convexity, the lower being well vaulted and of greater height than the upper, and ornamented with numerous longitudinal more or less unequal costæ separated by narrow grooves, more prominent costæ being placed at equal distances over the surface, with two or three finer subsidiary ones between. There are faint indications of distant concentric lineations, as well as obscure evidence of asperities on the primary longitudinal ribbing. This specimen in its oblong, oval contour and general structure of the surface-sculpture resembles Fuchs's interpretation of Brongniart's species *Sp. cisalpinus*, which was obtained from the Grumi Mountains of Castel-Gomberto, Northern Italy, and is regarded as of Oligocene (Stampian) age. The specimen figured by Fuchs is larger and in better condition than the original, which was collected in the same area of Northern Italy, but in rocks said to be 'Schioschichten' and therefore of Aquitanian age. Both Hœrnes and Oppenheim have recognized the species in similar rocks, while the latter author has also identified it as part of the Priabonian fauna. The species, therefore, ranges from the Priabonian to the Aquitanian.

Dimensions.—Length=58 millimetres; height (approximate)= 80 mm.; diameter=35 mm.

Occurrence.—The matrix is pale and of marly character, with a reddish tinge in places. Microscopically it is made up of *Lithothamnion*, *Operculina*, etc., but without *Nummulites*.

Locality.—Ain Sciahat (above camp).

PECTEN VEZZANENSIS Oppenheim. (Pl. XLV, figs. 3 & 4.)

Pecten arcuatus R. Hœrnes, Jahrb. K.K. Geol. Reichsanst. vol. xxviii (1878) pp. 18, 29, *non* Brocchi.

Janira arcuata Vinassa de Regny, Boll. Soc. Geol. Ital. vol. xv (1896) p. 204.

Pecten (Janira) vezzanensis Oppenheim, Zeitschr. Deutsch. Geol. Gesellsch. vol. lv (1903) pl. ix, figs. 6–7 *a* & p. 173.

Remarks.—Dr. Oppenheim has described and figured a small shell called *Pecten vezzanensis*, from the Aquitanian (Schioschichten) rocks of Vezzan near Belluno, in Northern Italy, which had been previously referred to in literature by Dr. Hœrnes and Dr. P. Vinassa de Regny as *P. arcuatus*, a species characteristic of the Priabonian horizon.

The specimen now assigned to this species consists of one lower valve attached to some matrix, possessing twenty-one rather smooth-topped ribs with minute transverse striations decorating the intermediate furrows; the ears are proportionately deep, the surface of the byssal one being ornamented with three or four radial costæ, crossing a set of closely arranged, fine, vertical striations, while the other is furnished with very obscure oblique lines. The umbonal area is narrow, less incurved than in other related forms, and possessed of fairly long concave lateral margins which meet a well-rounded ventral border. The valve is also moderately convex.

Dimensions (lower valve).—Length = 15 millimetres; height = 15 mm.

Occurrence. — In a greyish marly-looking rock containing obscure *Operculina*.

Locality.—Ain Sciahat.

ÆQUIPECTEN cf. PASINII (Meneghini). (Pl. XLIV, figs. 4 & 5.)

Pecten pasinii Meneghini, 'Pal. Sardaigne' 1857, pl. H, fig. 13 & p. 591; Schaffer, Jahrb. K.K. Geol. Reichsanst. 1900, vol. xlix, pl. xvii, figs. 1–3 *b* & p. 661; Oppenheim, Zeitschr. Deutsch. Geol. Gesellsch. 1903, vol. lv, pl. ix, figs. 2–3 & p. 162.

Remarks.—In the various figures of *Pecten pasinii* the dimensions of the valves show a greater length than height, thus differing from Cyrenaican examples, which are of equal measurement in those directions, namely 43 millimetres for the largest valve. The sculpture, which is similar on both valves, is, however, somewhat the same as in Meneghini's shell: that is, the costæ and grooves are furnished with closely-set, extremely fine, regular, and concentrically imbricating striations, this last character appearing to be less accentuated than in the true *P. pasinii*, where the striations are of rather simpler structure. Meneghini's *P. pasinii* was originally described from Sardinia, and more recently it has been recognized from Monte Brione in the Tyrol by Dr. Schaffer, and from Italian localities by Dr. Oppenheim, the latter author regarding the species as of Aquitanian age ('Schioschichten').

One of the small specimens is attached to an example of *Æquipecten camaretensis* and another to *Æquipecten zitteli*.

Occurrence.—In a grey marly matrix containing *Operculina*; and a doubtful fragment in a greensand matrix, weathering red, from Birlibah.

Localities.—Fountain of Apollo, Cyrene (British Museum specimen—L 16342); and Ain Sciahat, above camp; ? Birlibah.

ÆQUIPECTEN ZITTELI (Fuchs). (Pl. XLV, figs. 7 & 8.)

Pecten zitteli Fuchs, Palæontographica, 1883, vol. xxx, pl. vii (ii) figs. 1–12 & p. 41 (23).

Pecten (Chlamys) zitteli Kilian, 'Mission d'Andalousie' Mém. Acad. Sci. France, 1889, ser. 2, vol. xxx, pl. xxxiii, fig. 9 & p. 709.

Æquipecten zitteli Sacco, 'Moll. Terr. Terz. Piemonte' 1897, pt. 24, p. 31.

Pecten (Æquipecten) zitteli R. B. Newton, Geol. Mag. 1899, p. 209; Blanckenhorn, Centralblatt Mineral. &c. [Stuttgart] 1900, p. 211, and Zeitschr. Deutsch. Geol. Gesellsch. 1901, vol. liii, p. 108.

Pecten zitteli Dollfus, in Pachundaki, 'Contrib. Étude Géol. Marsa Matrouh (Marmarique)' Revue Internat. Égypte, vol. iv, pt. ii, 1907, p. 32.

Remarks.—Quite a number of pectinoid shells appear to be referable to this species, which belongs to the Helvetian beds of Egypt (Siwa Oasis, etc.) and the Marmarican Plateau near Alexandria. From its variability in sculpture the species is often difficult to determine, the Cyrenaican specimens offering no exception to this changeable character of the ornament. Some of the valves exhibit slightly tripartite or divided costæ, whereas others are more rounded; lines of minute granulations frequently cover the grooves and the sides of the costæ, while an extremely fine

imbricated surface adorns the summits of the costæ. The valves vary in size as the originals figured by Fuchs, being generally of the same length as height, one of the largest yielding the following measurements:—Dimensions (left valve).—Length=43 millimetres; height=43 mm.

Occurrence.—Mostly in a marly-looking greyish limestone, sometimes weathering reddish-brown, with *Operculina* and *Lithothamnion*.

Localities.—Cyrene; Ain Sciahat; Ain Sciahat, above camp; before the shrine of Sidi Mahomet Mahridi, east of Slonta; west of Labruk.

ÆQUIPECTEN CAMARETENSIS (Fontannes). (Pl. XLV, figs. 5 & 6.)

Pecten camaretensis Fontannes, 'Études Période Tert. Bassin du Rhône: pt. 3, Bassin de Visan' 1878, pl. iii, fig. 2 & p. 90.

Remarks.—This form of pectinoid shell is represented by several specimens in different states of preservation, although a more complete valve is available for examination which does not belong to Prof. Gregory's collection, but was presented to the British Museum (Natural History) some time since by Mr. H. Weld-Blundell, who obtained it from the rocks at the Fountain of Apollo, Cyrene. It shows the subrotund and characteristic form of the species, together with the sixteen or seventeen rounded radial costæ widely separated in the ventral region and covered with numerous delicate squamose concentric lines, the intermediate grooves being ornamented with longitudinal rows of minute scabrous growths. Parts of both auricles are present, ornamented with fine lines of radial granulations.

Dimensions (left valve).—Length=50 mm.; height=50 mm.

The species is characteristic of rather low Helvetian, being found in the Visan area of France with *Ostrea crassissima*, as originally mentioned by Fontannes. A varietal form is figured and referred to by Prof. Sacco as occurring in corresponding beds of Italy,[1] which he includes under Matheron's *P. scabriusculus*; while Dr. Blanckenhorn records a related form (cf. *camaretensis*) from the Miocene of Barka in Cyrenaica.[2]

Occurrence.—The specimens are in a greyish sandy matrix containing *Operculina*.

Localities.—Fountain of Apollo, Cyrene; Ain Sciahat, above camp; Ain Sciahat.

ÆQUIPECTEN SCABRELLUS (Lamarck).

Pecten scabrellus Lamarck, 'Hist. Nat. Anim. sans Vert.' 1819, vol. vi, pt. 1, p. 183.

Æquipecten scabrellus Sacco, 'Moll. Terr. Terz. Piemonte' 1897, pt. 24, pl. viii, figs. 1–6 & p. 24.

Remarks.—According to Prof. Sacco, this species is characteristic of the Helvetian Miocene, although certain varieties occur in

---

[1] 'Moll. Terr. Terz. Piemonte' 1897, pt. 24, pl. ix, fig. 2 & p. 32.

[2] Zeitschr. Deutsch. Geol. Gesellsch. vol. liii (1901) pp. 104, 108, 123.

Pliocene strata. In contour it presents generally an oblique appearance, bearing some fifteen radial costæ divided by well-pronounced sulcations, which are furnished with a squamose-denticulate surface. The valves generally have about the same dimensions each way, one showing a measurement of 33 mm. in length and height.

Occurrence.—In a grey marly-looking matrix, associated with good examples of *Operculina*.

Localities.—Ain Sciahat, above camp; Ain Sciahat, Tombs of Cyrene (=Weld-Blundell Collection, British Museum).

ÆQUIPECTEN HAUERI (Michelotti). (Pl. XLIV, fig. 6.)

Pecten magnificus Michelotti, Ann. Sci. Inst. Lombardo-Veneto, 1839, vol. ix, p. 127, *non* G. B. Sowerby, 1835.

Pecten haueri Michelotti, 'Descr. Foss. Terr. Miocènes Italie Septent.' 1847, pl. iii, fig. 13 & p. 88.

Æquipecten haueri Sacco, 'Moll. Terr. Terz. Piemonte' 1897, pt. 24, pl. vii, figs. 1–10 & p. 22.

Pecten haueri Oppenheim, Zeitschr. Deutsch. Geol. Gesellsch. 1903, vol. lv, pl. viii, fig. 5 & p. 154.

Remarks.—Referred to this species is a fragmentary valve, with obscure remains of auricles, but which in sculptural characters and general contour appears to completely agree with this form of pectinoid shell.

The greater part of the umbonal surface is preserved, together with a few of the costæ on the left side of the specimen, otherwise the remainder is stripped of its test and appears as an internal cast. About eighteen costæ can be counted, which are fine and well rounded in the umbonal area, but afterwards become flattened and spreading, especially at the flanks. The early ribs are microscopically and closely imbricated. The great feature of the shell, however, concerns the numerous close radial lines made up of microscopical granulations which give a divided or tripartite character to the costæ as well as decorating the intermediate sulcations. Distant concentric striations are also present.

Dimensions (approximate).—Length = 65 millimetres; height = 55 mm.

This species was originally described from Northern Italy in beds now regarded as of Helvetian age; in recent years Dr. Oppenheim has recognized it as part of the 'Schioschichten' fauna, and consequently as belonging to the Aquitanian horizon.

Occurrence.—In a cream-coloured limestone with minute black specks of mineral matter, and externally weathering to the usual reddish-brown ferruginous colour; it contains *Operculina*.

Locality.—Birlibah.

OOPECTEN ROTUNDATUS (Lamarck). (Pl. XLIV, fig. 3.)

Pecten rotundatus Lamarck, 'Hist. Nat. Anim. sans Vert.' 1819, vol. vi, pt. 1, p. 179; Deshayes, 2nd ed. of same work, 1836, vol. vii, p. 156; Fuchs, Denkschr. K. Akad. Wissensch. Wien, 1879, vol. xli, pt. 2, pl. ii, figs. 1–2 & p. 104; Fontannes, 'Études Stratigr. Paléont. Période Tert. Bassin du Rhône: le Bassin de Crest' 1880, vol. vi, pl. v, fig. 1 & p. 161.

Oopecten rotundatus Sacco, 'Moll. Terr. Terz. Piemonte' 1897, pt. 24, pl. xv, figs. 14–15 & p. 54.

Pecten (Oopecten) rotundatus R. B. Newton, 'Marine Tertiary [Miocene] Mollusca from Lake Urmi, Persia' Linn. Soc. Journ. (Zool.) 1900, vol. xxvii, pl. xxix, fig. 1 & p. 443.

Remarks.—The pectinoid shells referred to this species have well accentuated costæ varying in number like the original from about fourteen to sixteen, which are at first well rounded but later become more or less depressed at the summits; both the costæ and furrows widen out ventrally and are of equal width. The surface of the valve is covered with closely-set concentric striations, which are more obscure over the umbonal region. The best-preserved specimen in the collection shows an almost similar length and height of about 70 millimetres, but the margins are by no means perfect, otherwise it is possible that the length may have exceeded the height, as in normal forms of the species; the auricles are only partly seen. The species was originally described from Vence, between Grasse and Nice in France, under the following diagnosis:—testa suborbiculari utrinque convexa; radiis 14 ad 16 distinctis, convexis, versus limbum planulatis, two figures in Knorr's old folio work[1] being mentioned as examples; but it is evident, as pointed out by Deshayes, that they belonged to entirely different forms of pectiniform shells; moreover, one (*op. cit.* fig. 5) was from Malta, the other (fig. 6) was from Algiers. The figure of the Maltese specimen comes probably nearest to a proper conception of the present species although of less size, and as Deshayes explained, it should not be considered the same shell because only seven costal ribs are present. Bearing in mind also that this same figure represents an imperfectly preserved specimen, it is advisable to dismiss it from synonymy, a plan followed by most subsequent authors. According to Prof. Sacco the species ranges from the top of the Aquitanian to the Helvetian in Italy. Fuchs regarded the Vence forms as of 'Horner Schichten' age, and consequently Aquitanian or lowest Miocene; Fontannes's Rhone Valley specimens were considered as Lower Helvetian; while the Persian specimens from the Siokuh Mountains and from Lake Urmi have been bracketted with the Helvetian or Burdigalian stages of the Miocene.

Occurrence.—The matrix varies from a cream-coloured or greyish limestone to a yellowish, arenaceous marly-looking rock with minute blackish grains; and all have the usual external ferruginous tinting. *Operculina* and Nullipore structures (in valves from Ain Sciahat) are frequent, besides *Lepidocyclina elephantina*, identified by Mr. Chapman (see his report on the Foraminifera of the present collection, p. 660), who states that it indicates either a Stampian or an Aquitanian age. The presence of the mollusc, however, in this case would favour the latter horizon.

Localities.—West of Labruk; Birlibah; Wadi Umzigga (second camp); and Ain Sciahat.

---

[1] 'Recueil de Monumens des Catastrophes . . . Pétrifications' vol. ii (1768) sect. 1, p. 77 & pl. B I c, figs. 5–6.

[Luciniform Casts.]

Remarks.—These specimens consist of a number of casts of rather small size, which may belong to either *Lucina* or *Diplodonta*. They have very convex and somewhat globular valves, but it is not possible to determine them either zoologically or geologically. They are therefore included doubtfully among the Aquitanian series.

Occurrence.—The specimens are composed of a cream-coloured and fine-grained limestone in which no foraminifera are observable.

Localities.—Lamludeh; below the Mudir's House, Ain Sciahat; Ain Sciahat.

V. PRIABONIAN.

Quite a large series of the Cyrenaican mollusca are regarded as of Priabonian age, on account of their resemblance to those found in the Uppermost Eocene or Lowest Oligocene deposits of the Vicentino district of Northern Italy. Prof. Suess first gave prominence to this term for the age of these beds by describing them as the 'Gruppe von Priabona,' after the name of that region of Italy.[1]

The chief authority at the present day on these deposits is undoubtedly Dr. Oppenheim,[2] his memoir on 'Die Priabonaschichten & ihre Fauna' comprising a voluminous survey of the subject. A brief allusion may be made to those areas of Northern Africa which have produced fossils of Priabonian age, and we are probably indebted to Zittel[3] for our earliest knowledge of this subject. During his survey of the Libyan Desert of Egypt, Zittel collected fossils from certain deposits occurring between Rharten and Aradj near the Oasis of Siwa in Egypt, which were recognized as equivalent to the Priabonian fauna of Northern Italy and resembling that of the highest Eocene deposits of Switzerland, Hungary (Bakony Forest), Nice, Biarritz, Cassinelle, Dego, and Gaas. These Egyptian beds, immediately overlying the *Nummulites-gizehensis* Zone and regarded as belonging to the Lutetian series of the Eocene, contained mollusca which were determined by Mayer-Eymar, as well as foraminifera studied by De la Harpe, the whole constituting a fauna which Zittel scheduled as Upper Eocene or Ligurian on his correlation-chart (*op. cit.* p. xciii); these fossils included *Ostrea ventilabrum*, *O. fimbriata*, *Pecten biarritzensis*, *Nummulites fichteli*, *N. intermedia*, *N. ruetimeyeri*, etc.

Dr. Schweinfurth in 1886 and 1889 reported the occurrence of the uppermost Eocene strata to the west of Dimé, in the Fayûm district of Egypt.[4] Fossils of Tongrian age were determined in the same year by Mayer-Eymar from near Cairo.[5] Further material

---

[1] 'Ueber die Gliederung des Vicentinischen Tertiärgebirges' Sitz. K. Akad. Wissensch. Wien, vol. lviii, pt. i (1868) p. 272.

[2] Palæontographica, vol. xlvii (1900–1901) pls. i–xxi & pp. 348.

[3] *Ibid.* vol. xxx, pt. i (1883) p. 124.

[4] Zeitschr. Gesellsch. Erdkund. Berlin, vol. xxi (1886) p. 141, and Petermann's Mitth. vol. xxxv (1889) p. 2.

[5] Viertelj. Nat. Gesellsch. Zürich, vol. xxxiv (1889) pp. 191–208 & pl. i.

was dealt with in subsequent papers by Mayer-Eymar, based on the examination of fossils from the same region, among some of the more typical shells being *Natica* (*Ampullina*) *crassatina*, which the same author had identified, among Schweinfurth's uppermost Eocene fossils from the Dimé area of the Fayûm.[1]

In 1896 Mayer-Eymar[2] mentioned some imperfect fossils collected at Kum el Kashab (near Cairo) which he supposed to be Lower Ligurian and resembling those found near Dimé, as they probably represented *Ostrea cyathula* var. *fimbriata* and *Pecten* (*Neithea*) *arcuatus*, etc. Prof. Depéret published in 1896[3] some observations on the Tertiaries of Algeria. He had collected (*op. cit.* p. 1117) at Beni-Amram certain fossils including Operculines, small *Cardita*, and a small *Pecten* probably identical with *Janira fallax* Michelotti (=*Pecten arcuatus*), from the Tongrian of Dego. This limited and incomplete fauna he regarded as analogous to the Tongrian beds with *Nummulites fichteli*, of Northern Italy and the Ligurian Apennines. Priabonian rocks in Tunisia were recognized by M. Flick in 1900,[4] his palæontological evidence including such forms as *Scutella* and *Clypeaster*, related to *S. striatula* and *C. biarritzensis* which occur at Biarritz and Priabona in Italy; *Pecten nucalis* Locard = *P. michelotti* D'Archiac, corresponding to examples from Biarritz having non-carinated costæ, and which was stated to be equally common in the Venetian Alps; another *Pecten* showed affinities with *P. tripartitus* and *P. gravesi* of D'Archiac; there was also a variety of *Cytherea incrassata* and *Pholadomya puschi*, found at Salcedo and Sangonini. The author regarded the facies of this fauna as equivalent to that of the Venetian Alps and belonging to the uppermost Eocene.

In Dr. Blanckenhorn's memoir on the 'Palæogene' of Egypt,[5] the *Nummulites intermedius* and *N.-fichteli* Beds of the Aradj district of Egypt are recognized as of Lower Oligocene or Ligurian age, the species being again mentioned as occurring in rocks of similar age in Sinai, Palestine, and Syria. The presence of the Upper Eocene or Bartonian in the same area (Aradj) is not acknowledged by this author. He further recognizes the Kum-el-Kashab fossils, including *Natica crassatina*, etc., as of Lower Oligocene or Ligurian age. On p. 460 of the same memoir Dr. Blanckenhorn regards these beds as Lower Ligurian, stating them to be the equivalent of the Upper 'Biarritzschichten,' Latdorfian, Priabonian, or Ludian of Northern Italy, the Pyrenees, and Northern Germany.

Similar rocks are present in Algeria, Dr. Pervinquière having collected *Pecten arcuatus* and *Ostrea brongniarti* at Boghari, this author remarking that those fossils are found in the Priabonian, although having their maximum occurrence in the Oligocene.[6]

---

[1] Bull. Inst. Égyptien, ser. 3, vol. iv (1893) pp. 371–373.

[2] *Ibid.* vol. vi (1896) p. 94.

[3] Bull. Soc. Géol. France, ser. 3, vol. xxiv (1896) p. 1115.

[4] C. R. Acad. Sci. Paris, vol. cxxx (1900) pp. 148–50.

[5] Zeitschr. Deutsch. Geol. Gesellsch. vol. lii (1900) pp. 403–79.

[6] 'Étude Géol. Tunisie Centrale' 1903 [French Govt. Publication] p. 205.

Quite recently MM. Louis Gentil & Jean Boussac[1] have referred to the presence of Priabonian rocks in the north of Morocco (near Tangier) containing *Orthophragmina* and *Nummulites fabiani* of Prever.

It will be observed, therefore, that Priabonian fossils have been collected in North African countries as well as in Syria and Palestine, one of the characteristic shells of Tunisia and Algeria being *Pecten arcuatus*. In the Siwa district of Egypt the beds contain *Nummulites intermedius* and *N. fichteli*, besides a number of mollusca but not including *Pecten arcuatus*. From Cyrenaica several examples of this *Pecten* have been obtained, but the two species of *Nummulites* have not been determined by Mr. Chapman in his report on that group, which suggests a resemblance to the conditions prevalent in Tunisia and Algeria, where *N. intermedius* appears not to be known.

The European home of the Priabonian rocks is in the Venetian area of Northern Italy, but they also occur in the Balearic Islands (Majorca), at Biarritz, in the Swiss, Bavarian, and Eastern Alps, the Carpathians, Hungary, and the Balkan Peninsula. Such rocks are to be found also in Armenia,[2] Asia Minor, India, Madagascar, etc., references to all of which must be sought for in Dr. Oppenheim's memoir already mentioned. In adopting Priabonian as the horizonal age for these fossils, it should be quite understood that it may be regarded either as forming the Uppermost Eocene or the Lowest Oligocene, and preferably the latter. Various authors who have studied the Priabonian fauna have differed somewhat as to its position in the geological series. Zittel regarded it as belonging to the highest Eocene or Ligurian, Schweinfurth as Upper Eocene, Mayer-Eymar as both Tongrian and Ligurian, Flick as the Uppermost Eocene, Dr. Blanckenhorn as Lower Oligocene or Ligurian, and Prof. Depéret as Tongrian.

These fossils come from the neighbourhood of Slonta, Merj, Messa, Kuf Narbea, Mersa Susa, Bint, Derna, shrine of Sidi Abdullah, Wadi Khumas, Ain Hafra, Lamludeh, and Ain Sciahat.

Gastropoda.

EUSPIRA cf. POSSAGNENSIS Oppenheim. (Pl. XLVI, fig. 11.)

Natica (Euspira) possagnensis Oppenheim, Palæontographica, 1901, vol. xlvii, pl. vi, fig. 13 & p. 197.

Remarks.—This specimen consists of a limestone cast with the two latest whorls only, the posterior portion of the spire not being preserved.

Although of somewhat smaller size, it has much the form of Oppenheim's *E. possagnensis*, described and figured from the Priabonian rocks of Possagno in Austrian Italy. The front view

---

[1] Bull. Soc. Géol. France, ser. 4, vol. x (1910) p. 484.

[2] See F. Oswald, 'The Geology of Armenia' 1906, pp. 427 *et seqq.*

exhibits an inflated body-whorl with an oval aperture of considerable width, and moreover furnished with a well-rounded external margin. The dorsal aspect shows an extensive basal whorl with a prominently tabulated and oblique sutural area, above being a fairly deep penultimate whorl, with a rather compressed surface. The columella is obliterated by matrix.

Dimensions.—Length = 60 millimetres; width = 57 mm.

The specimen also shows some resemblance to Lamarck's *Natica hybrida*[1] from the European and Egyptian Eocene deposits, in the possession of a tabulated suture and compressed sides to the earlier whorls, but that has a comparatively shorter spire and is generally of more globose contour.

Occurrence.—This cast is associated with a cream-coloured limestone, weathering reddish-brown, which is largely composed of *Nummulites.*

Locality.—East of Ain Hafra, east of Cyrene.

AMPULLINA CRASSATINA (Lamarck).

Ampullaria crassatina Lamarck, Ann. Mus. Hist. Nat. (Paris) 1804, vol. v, p. 33; and *ibid.* 1806, vol. viii, pl. lxi, fig. 8.

Natica crassatina Deshayes, 'Descr. Coq. Foss. Paris' 1832, vol. ii, pl. xx, figs. 1–2 & p. 171.

Natica (Ampullina) crassatina Schauroth, 'Verzeichn. Versteinerungen' 1865, p. 252.

Natica crassatina Fuchs, Denkschr. K. Akad. Wissensch. Wien, 1870, vol. xxx, p. 159.

Megatylotus crassatinus Sacco, 'Moll. Terr. Terz. Piemonte' 1891, pt. 9, p. 13; and Cossmann, Journ. Conchyl. [Paris] 1892, vol. xl, p. 355.

Natica (Ampullina) crassatina Mayer-Eymar, Bull. Inst. Égyptien, 1893, ser. 3, no. 4, p. 373.

Natica crassatina Blanckenhorn, Zeitschr. Deutsch. Geol. Gesellsch. 1900, vol. lii, pp. 466–67.

Remarks.—This fossil is a moderately large limestone-cast, which has suffered more or less a dorso-ventral compression. In general form it is transversely subovate; the body-whorl, from the dorsal aspect, is extensive and only moderately convex, and it is surmounted by two earlier whorls having deep and depressed sides; otherwise, the further elements of the spire are not preserved. The suture is canaliculated and slightly tabulate, and the aperture is ample with a semicircular labrum, but the columelloid details are mostly obscured by matrix, so that the presence or otherwise of an umbilical cavity is a little uncertain. Compared with Deshayes's figures, the cast in question exhibits a greater breadth, as it possesses a wider aperture and a more produced curvature to the outer lip.

Dimensions.—Length (approx.) = 75 mm.; breadth = 70 mm.

This species is chiefly characteristic of Lower Oligocene rocks (= Tongrian), being known from England, European countries (France, Italy, etc.), and Egypt, as recorded by Mayer-Eymar and Dr. Blanckenhorn. The species also extends to the Stampian stage of the same period, having been identified from the 'Gomberto-Schichten' of Italy.

---

[1] See G. P. Deshayes, 'Descr. Coq. Foss. Paris' vol. ii (1832) p. 172 & pl. xix, figs. 17–18.

Occurrence.—The specimen is associated with a cream-coloured limestone containing various forms of foraminifera, including *Orthophragmina*, etc.

Locality.—Lamludeh.

ROSTELLARIA sp. (Pl. XLVI, fig. 10.)

Remarks.—Under this genus are included two limestone-casts of fragmentary preservation, both exhibiting parts of the basal and penultimate whorls. These whorls are depressed and divided by a prominent suture, the basal being furnished with a median obtuse angulation from which descends obliquely and conically the remainder of the whorl to the somewhat tapering extremity. The aperture is elongate, more or less of oval shape and nearly perpendicular, and at the base of the columella is a deep slit-like cavity from which originally would have extended a possible narrow canaliculation. The specimens are of different sizes, and evidently belonged to fairly large individuals like the *Strombus amplus* of Solander = *Rostellaria macroptera* of Lamarck,[1] although the casts give no indication of the extensive labrum which characterizes that species.

Dimensions in millimetres:—

	Larger specimen.	*Smaller specimen.*
Length	63	54
Width (front aspect)	45	37

It is interesting to note that Dr. Oppenheim[2] refers to some doubtful fragments of a *Rostellaria* found in the Priabonian clays of Possagno, of the group *macroptera*, and with resemblances to *R.* cf. *marceauxi* of Deshayes, described and figured by Fuchs from beds of similar age in Russia (Kalinovka), although the casts from Cyrenaica show no particular relationship to this last-named form.

Occurrence.—Specimens are associated with a light-coloured limestone, weathering to a reddish tint, in which *Nummulites* and other microzoa are observable.

Localities.—'After shrine of Sidi Abdullah'; south-east of Messa.

GISORTIA GIGANTEA (Münster in Goldfuss). (Pl. XLVI, fig. 8.)

Strombus giganteus Münster in Goldfuss, 'Petrefacta Germaniæ' 1844, vol. iii, pl. clxix, fig. 3 & p. 14.

Ovula (Strombus) gigantea Lefèvre, Ann. Soc. Malacol. Belgique, 1878, vol. xiii, pl. iii, figs. 1–3, pl. iv, figs. 1–3, pl. v, fig. 1, pl. vi, fig. 1 & pp. 22–40.

Gisortia gigantea Oppenheim, Palæontographica, 1906, vol. xxx, pt. 3, No. 2, p. 304.

Remarks.—This is a small limestone-cast which may be referred to Münster's species, originally described from the Kressenberg (Lutetian) Beds.

Dimensions.—Length (approx.) = 55 mm.; width = 40 mm.

The species is characteristic of the Lutetian stage of the Eocene

---

[1] See G. P. Deshayes, 'Descr. Coq. Foss. Paris' vol. ii (1835) p. 620 & pls. lxxxiii, fig. 1, lxxxiv, fig. 1, lxxxv, fig. 10.

[2] Palæontographica, vol. xlvii (1901) p. 211.

System, and is known from Kressenberg and other Central European localities (Belgium, France, Russia), and Egypt. The Priabonian form is recognized by Lefèvre[1] as *Ovula gigantea* var. *hœrnesi,* from Northern Italy (Brendola), which chiefly seems to differ in the possession of an angulated marginal summit to the outer wall, although judging from the figures this is not constant, as some show a well-rounded shoulder to that region; it is, however, of much larger size, an adult example, according to Lefèvre, measuring 300 mm. in length and 200 mm. in width, whereas a full-grown form of *O. gigantea* is said by the same author to measure 145 mm. in height and 120 mm. in width. The present specimen has a very similar contour to D'Archiac's *Ovula murchisoni* from the Nummulitic rocks of India,[2] and it is probable that that species might more correctly be regarded as a synonym of *Gisortia gigantea.*

Occurrence.—In a cream-coloured limestone, no *Nummulites* being distinguishable with an ordinary lens.

Locality.—Mersa Susa.

VASUM cf. FREQUENS (Mayer-Eymar). (Pl. XLVI, fig. 9.)

Turbinella frequens Mayer-Eymar, Journ. Conchyl. [Paris] 1895, vol. xliii, pl. ii, fig. 7 & p. 47.

Vasum frequens Cossmann, Bull. Inst. Égyptien, 1901, ser. 4, no. 1, pl. i, fig. 7 & p. 179.

Turbinella frequens Oppenheim, Palæontographica, 1906, vol. xxx, pt. 3, No. 2, pl. xxiv, figs. 1–7 & p. 318.

Remarks.—This form is represented by a very rough limestone-cast in which the maximum width of the summit region is greater than the entire length of the shell. The earliest whorls are lost, but what is preserved of the spiral region shows it to be of a depressed character. The front aspect of the specimen is, however, important, as it possesses a well-inflated columellar surface on which can be traced three or four distant, obscure, nearly horizontal plications; the outer lip-margin is well rounded, and encloses a fairly open aperture of equal width throughout. The actual base is wanting, although, judging from the general contour, the canal would have been short and insignificant; the remains of a large spinose tubercle are present on the periphery.

Dimensions.—Length = 65 mm.; width (maximum) = 82 mm.

The specimen is evidently related to *Turbinella frequens,* described by Mayer-Eymar, which has since been well figured both by M. Cossmann and Dr. Oppenheim, the latter regarding it as occurring throughout the Mokattam Beds of Egypt, and even doubtfully suggesting that it is found in the *Nummulites-intermedius* (= Priabonian) Beds in the neighbourhood of Siwa in the same country. The species is at present restricted to Egypt.

Occurrence.—It occurs in a yellowish limestone containing *Nummulites*, *Lithothamnion*, and other organisms.

Locality.—Camp at Messa.

---

[1] Ann. Soc. Malacol. Belg. vol. xiii (1878) pp. 41–42 & pls. iii, iv, vii, viii.

[2] 'Descr. Animaux Foss. Nummulit. Inde' vol. ii (1854) p. 329 & pl. xxxiii, figs. 4–4 *a*.

Pelecypoda.

OSTREA cf. VENTILABRUM Goldfuss. (Pl. XLV, figs. 9–11.)

Ostrea ventilabrum Goldfuss, 'Petrefacta Germaniæ' 1833, vol. ii, pl. lxxvi, figs. 4–4 *c* & p. 13.

Ostrea prona S. V. Wood=*ventilabrum* S. V. Wood, Monogr. Pal. Soc. 1861 & 1871, pl. iii, fig. 3 & pp. 29, 181 (Index). [Eocene Mollusca.]

Ostrea ventilabrum A. von Kœnen, 'Norddeutsche Unter-Oligocän Mollusken-Fauna' Abhandl. Geol. Specialkarte Preussen, 1893, vol. x, pt. 5, pl. lxiv, figs. 5–8 & p. 1011; Rovereto, Atti R. Univ. Genova, 1900, vol. xv, p. 48; Blanckenhorn, Zeitschr. Deutsch. Geol. Gesellsch. 1900, vol. lii, p. 459.

Remarks.—This form is represented by a number of valves, the lower being of crescentic contour while the upper is more or less oblong. The lower valves are also fairly thick and arched, sometimes more spreading and depressed, and ornamented with numerous regular stout and radiating costæ which in their descent from the umbonal area are often dichotomized. The periodical growth-lines of the upper valve consist of irregularly spaced concentric ridges, the central area of the same valve being well elevated above a somewhat depressed ventral region. Both valves exhibit a slightly concave or nearly straight anterior margin. The umbones show a forward inclination, but are not exogyriform; while the adductor-sear impression is extensive and anteroventral.

Dimensions in millimetres (of adult valves belonging to different individuals):—

	Lower valve.	*Upper valve.*
Length...............	35	40
Height...............	53	65 (approximate).
Diameter............	25	15

Among oysters exhibiting similar relationships may be mentioned *O. fimbrioides* of Rolle, from the Austrian Oligocene,[1] *O. cyathula* of Lamarck, var. *fimbriata* Hœrnes, which Mayer-Eymar doubtfully recognized from fragments in the Lower Oligocene (Tongrian) of Egypt,[2] besides *O. ventilabrum* and *O. fimbriata*, both scheduled by Dr. Blanckenhorn from similar deposits of the same country. The true *O. ventilabrum* is therefore characteristic of Lower Oligocene deposits, and is known from England, Germany, Austria, Northern Italy, and Egypt.

Occurrence.—The valves are considerably worn, and mostly associated with a cream-coloured limestone weathering to a reddish colour, containing numerous *Nummulites*.

Localities.—South-west of Merj; east of the shrine of Sidi Mahomet Mahridi, east of Slonta; Old Cistern, east of Slonta; north of Slonta; Roman Fort, north-west of Slonta.

---

[1] Sitz. K. Akad. Wissensch. Wien, vol. xxxv (1859) p. 204 & pl. ii, figs. 1–3 *c*.

[2] Bull. Inst. Égyptien, 1896, ser. 3, no. 6, p. 94.

PECTEN ARCUATUS (Brocchi). (Pl. XLVI, figs. 3–6.)

Ostrea arcuata Brocchi, 'Conchiologia Fossile Subapennina' 1814, vol. ii, pl. xiv, fig. 11 & p. 578.

Pecten michelotii D'Archiac, Mém. Soc. Géol. France, 1850, ser. 2, vol. iii, pt. 2, pl. xii, figs. 20–21 & p. 435.

Janira fallax & deperdita Michelotti, 'Études sur le Miocène Inférieur de l'Italie Septentrionale' [Mem. Soc. Holl. Sci. Haarlem] 1861, pl. ix, figs. 4–7 & pp. 78–79.

Pecten michelottii Schauroth, 'Verzeichniss Versteinerungen, &c.' 1865, pl. xvi, fig. 3 & p. 201.

Cardium pereziforme Schauroth, *ibid.* pl. xviii, fig. 9 & p. 209.

Pecten arcuatus Fuchs, Denkschr. K. Akad. Wissensch. Wien, 1870, vol. xxx, pl. x, figs. 38–40 & p. 203.

Janira michelottii Hermite, 'Études géologiques sur les Iles Baléares (Majorque & Minorque)' [Thèses Faculté Sci. Paris] 1879, p. 223.

Cardium subtenuisulcatum Abich *non* Nyst, 'Geol. Forsch. in d. Kaukas. Ländern: Geologie des Armenischen Hochlandes' 1882, pl. vi, fig. 8 & p. 296.

Pecten nucalis Locard, 'Explorat. Scient. Tunisie: Descr. Moll. Tert. Inf.' 1889, pl. x, fig. 2 & p. 51.

Pecten subtripartitus Locard, *ibid.* pl. x, figs. 4 *b*–4 *c* & p. 52 (*non* D'Archiac).

Pecten arcuatus De Gregorio, Ann. Géol. Paléont. [Palermo] 1894, pt. 13, pl. iv, figs. 83–85 & p. 24; Sacco, 'Moll. Terr. Terz. Piemonte' 1897, pt. 24, pl. xxi, figs. 14–30 (and varieties, figs. 31–36) & pp. 65–67.

Pecten (Janira) arcuata Oppenheim, Palæontographica, 1900, vol. xlvii, p. 135.

Pecten arcuatus F. Oswald, 'Geology of Armenia' 1906, p. 427.

Remarks.—Some well-marked remains of this species form part of this collection, the lower or convex valve being that most frequently preserved. This exhibits from twenty to twenty-two costæ, which are rounded, smooth at the summits, strongly curved in their descent from the umbonal region, thus producing well-excavated outer lateral margins, and separated by sulcations which are about half the width of the ribs. Both valves possess equidistant transverse striations within the grooves which apparently never extend over the summits of the costæ.

There is only one fairly good example of an upper valve, from near Bint, which shows most of the details of costal structure previously referred to. It is besides very depressed, although exhibiting a slightly concave surface. The auricles are small in all specimens, and mostly obscure. The specimens vary slightly in size, the largest example of a lower valve giving the following

Dimensions (large lower valve):—Length = 34 millimetres; ight = 37 mm.; diameter = 16 mm.

This *Pecten* is characteristic of the Uppermost Eocene, or that part of the Lower Oligocene Beds which is regarded by Oppenheim and others as Priabonian. According to Prof. Sacco, the original locality of *P. arcuatus* should be Rocchetta Cairo of the Savona district of Liguria, where Oligocene strata are known, and not Rocchetta, near Asti, as given by Brocchi, where only Pliocene Beds are exposed. There are many other localities for this species in Northern Italy. It has also been recorded from Armenia, the Balearic Islands (Majorca), Biarritz, Algeria, and Tunisia. So far as Egypt is concerned, we have only a doubtful reference to its occurrence in that country made by Mayer-Eymar,[1] to the effect

---

[1] Bull. Inst. Égyptien, ser. 3, no. 6 (1896) p. 94.

that he had seen some indeterminable fragments resembling *Ostrea cyathula* var. *fimbriata*, and *Pecten* (*Neithea*) *arcuatus*, both forms characteristic of the Lower Tongrian, about 10 miles west of Cairo, at Kum el Kashab, an area where the fossil trees occur.

Occurrence.—Some of the specimens are associated with a cream-coloured, more or less compact, limestone weathering reddish-brown; the example from Messa is in a yellowish, sandy-looking, calcareous matrix; and another from near Bint, east of Derna, is found in a rather fragmental limestone varying from reddish brown to somewhat of a straw-colour. All the matrices contain an abundance of *Nummulites*.

Localities.—After Merj, the plateau to the south-west; wells at Merj; near Slonta; east of Slonta; Messa; Kuff Narbea, north of Wadi Firyah; Mersa Susa; near Bint, east of Derna.

ÆQUIPECTEN cf. DELETUS (Michelotti).

Pecten deletus Michelotti, 'Études sur la Miocène Inférieur de l'Italie Septentrionale' 1861 [Mem. Soc. Holl. Sci. Haarlem], pl. ix, figs. 1–3 & p. 77.

Æquipecten deletus and varieties, 'Sacco, Moll. Terr. Terz. Piemonte' 1897, pt. 24, pl. vi, figs. 1–7 & p. 19.

Remarks.—A single valve in the matrix showing only the basal area is, on account of the structure of the costæ, thought to be related to *P. deletus* of Michelotti, from the Tongrian of Northern Italy. These costæ, of which about eight are preserved in the specimen, are fairly broad, rounded, and furnished with somewhat coarse annulations; they are separated by deep sulcations of equal width with the costæ, the interiors of which are ornamented with four or five longitudinal rows of minute granulations.

Occurrence.—The specimen is associated with a cream-coloured limestone made up of *Lithothamnion*, *Nummulites*, etc.

Locality.—Derna.

ÆQUIPECTEN CYRENAICUS, sp. nov. (Pl. XLVI, figs. 1 & 2.)

Description (lower or right valve).—Shell fan-shaped, inequilateral, shallow, covered with about eighteen straight radial costæ, medially angulate, laterally oblique, and divided by widely open V-shaped furrows; grooves and ribs ornamented with narrow, closely-set, equally-banded annulations, which show a thickening or tuberculation on each side at the bases of the sulcations; posterior expansion (only partly preserved) with three or four oblique rows of small contiguous granulations.

Dimensions:—Length=55 mm.; height (about) =50 mm.

Remarks.—The suborbicular or fan-shaped contour of this valve would associate it with the *P.-opercularis* type of pectinoid shells, and therefore it should be regarded as belonging to Fischer's genus *Æquipecten*. The ornamentation of the costæ and furrows is singularly different from that seen in other forms of this genus. There are no striations radiating from the umbonal region, the sculpture being entirely composed of the closely-fitting, equally

narrow bands which give a regularly-imbricate surface to the angulate ribs and sulcations.

The specimen is very imperfect in the umbonal direction, and only a fragment is preserved of the posterior auricle, no part of the anterior wing being present; a part of the ventral margin is also fractured.

Probably its nearest ally is a form described and figured by D'Archiac as *Pecten subopercularis*, from the Nummulitic deposits of Bayonne; but in that shell the costæ are far more numerous and, moreover, fine longitudinal striations ornament the grooves, which are not seen in the present specimen, otherwise the imbricating structure of the costæ is very similar.[1]

Occurrence.—The specimen is associated with a pinkish limestone full of *Nummulites* and *Lithothamnion*, the latter organism showing out very plainly as small white, more or less globular masses. The matrix is entirely different from anything else in the collection.

Locality.—Above camp at Ain Sciahat.

VULSELLA sp. (Pl. XLVI, fig. 7.)

Description (left valve).—Specimen representing an elongate, narrow valve, the posterior side of which shows a long marginal curvature extending from the umbonal region; the lateral margins were probably more or less parallel, although the anterior one is absent; the surface is smooth and slightly convex.

Dimensions:—Length = about 25 mm.; height = 55 mm.

Remarks.—This valve is very much fractured, but on account of its lingulate contour it is possibly related to *Vulsella crispata* of Paul Fischer, which Dr. Oppenheim identifies from the *Nummulites-intermedius* Beds of Egypt,[2] and in lower horizons of the Eocene of the same country.

Occurrence.—It is attached to a compact cream-coloured limestone, with a smaller example of the same genus in close proximity showing concentric laminations. This matrix weathers to a reddish colour, and contains *Nummulites*.

Locality.—Base of cliffs, south-east of Merj.

VULSELLA cf. EYMARI Oppenheim.

Vulsella eymari Oppenheim, Palæontographica, 1903, vol. xxx, pt. 3, No. 1, pl. vi, figs. 1–1 *a* & p. 74.

Remarks.—External view of a left valve with an eroded surface, and showing very obscure remains of concentric striation. It is of oblong form with nearly parallel sides; an antero-dorsal projection is present indicating an extension of the hinge-region,

---

[1] Mém. Soc. Géol. France, ser. 2, vol. iii, pt. 2 (1850) p. 436 & pl. xii, figs. 19–19 *a*.

[2] Palæontographica, vol. xxx, pt. 3 (1903) No. 1, p. 68 & pl. iv, figs. 1–3 & 8, pl. vi, figs. 12–13 & 15.

which is succeeded below by a prominent notch or excavation; the valve is moderately convex, with gently sloping sides.

Dimensions:—Length=38 millimetres; height=55 mm.

In contour and size this valve resembles *Vulsella eymari* of Dr. Oppenheim, from the Libyan Eocene deposits of Egypt, and its affinities are probably with that species. If such is the case, then it must be assumed that the prominent concentric laminæ distinguishing Oppenheim's specimen must have disappeared through weathering or otherwise. Both forms exhibit the anterior projection of the cardinal area, but the margin below forms more of a notch in the present shell, than a continuous excavation as in the example from Egypt. This extension of the hinge-area and the presence of the notch are apparently not seen in recent examples of the genus, and although suggestive of byssal characters, it is stated in Fischer's 'Manuel' that *Vulsella* has no byssal organ.

Occurrence.—A cream-coloured limestone weathering reddish is the associated matrix; well-preserved *Nummulites* are present.

Locality.—East of Slonta.

SPONDYLUS sp.

Remarks.—This specimen is of rather small size, and in a worn and cracked condition. It possesses both valves in the closed state, with an imperfect dorsal area showing only the incurved umbones without indication of hinge-expansions. In general form having a greater length than height, it assumes much the contour of some examples of *Sp. rouaulti* D'Archiac,[1] from the Indian Eocene, but differs from that species in sculpture by possessing a more uniform costal system in which the ribs are of one order throughout. These costæ are numerous (about thirty), fine, rounded, and divided by grooves which, in the ventral direction, are nearly twice their width, but are much narrower over the umbonal region. On the summits of the costæ there appear to be occasional minute asperities which, however, are very obscure. No transverse striations are observable in the sulcations, such as characterize *Sp. rouaulti.*

Dimensions:—Length = 32 millimetres; height = 27 mm.; diameter=15 mm.

Occurrence.—In a cream-coloured marly limestone weathering to a straw-colour; no *Nummulites* distinguishable.

Locality.—North of Slonta.

TRACHYCARDIUM cf. GRANCONENSE Oppenheim.

Cardium (Trachycardium) granconense Oppenheim, Zeitschr. Deutsch. Geol. Gesellsch. 1896, vol. xlviii, pl. iv, fig. 14 & p. 94, and Palæontographica, 1901, vol. xlvii, p. 164.

Remarks.—This form consists of a single left valve in limestone, well inflated, of equal length and height, possessing numerous costæ and grooves which are furnished with a minute

---

[1] 'Descr. Anim. Foss. Nummulit. Inde' vol. ii (1854) p. 272 & pl. xxiv, figs. 6–8.

imbricating sculpture strongly resembling that present in Dr. Oppenheim's *Trachycardium granconense*, a Priabonian species from the Venetian Alps.

The specimen is much weathered, so that the ornamentation is strongest in the grooves, and it is only very obscurely and occasionally seen to pass over the ribs themselves, which through erosion are mostly smooth at the summits.

Dimensions (left valve).—Length = 42 millimetres; height = (about) 42 mm.; diameter = 13 mm.

Occurrence.—In a hard cream-coloured limestone weathering to a reddish tint and containing *Nummulites*.

Locality.—Mersa Susa.

LUCINA cf. PHARAONIS Bellardi.

Lucina pharaonis Bellardi, Mem. R. Accad. Sc. Torino, ser. 2, vol. xv (1854–55) pl. ii, fig. 12 & p. 190; Oppenheim, Palæontographica, 1903, vol. xxx, pt. 3, No. 1, pl. xiii, figs. 1–2, pl. xv, fig. 6 & p. 124.

Remarks.—There are several casts of a luciniform shell which in general aspects show relationship to Bellardi's *L. pharaonis*, from the Mokattam Beds of Egypt. They present the same suborbicular contour; the valves are also fairly well inflated, and mostly exhibit the postero-dorsal compression as well as a nearly horizontal antero-dorsal line immediately below the umbones. Obscure muscular and other markings are seen on the surfaces, although generally much too indistinct for definition; occasionally, concentric striations are preserved. The largest example shows the following measurements:—

Dimensions (with closed valves):—Length = 51 millimetres; height = 47 mm.; diameter = 30 mm.

According to Dr. P. Oppenheim, the species is restricted to Egypt and Algeria, Coquand's[1] *L. mœvusi* from the latter region being now recognized as the same shell. The species ranges throughout the Mokattam Beds of Egypt; but, in Algeria, it is said to occur in the Suessonian stage of the Eocene deposits.

Occurrence.—Specimens mostly in a cream-coloured limestone weathering to various reddish tints, and sometimes associated with *Nummulites*.

Localities.—Top of pass leaving Wadi Khumas; two hours before reaching the shrine of Sidi Mahomed (before Slonta); Merj Wells; Kuff Narbea, north of Wadi Firyah.

LUCINA cf. NOKBAENSIS Oppenheim.

Lucina nokbaensis Oppenheim, Palæontographica, 1903, vol. xxx, pt. 3, No. 1, pl. x, fig. 13 & p. 139.

Remarks.—The specimen thought to be related to this species is an internal cast, with united valves of fairly large size and of moderate convexity. Its contour, however, is rounded, and

---

[1] 'Géologie & Paléontologie de la Région Sud de la Province de Constantine' 1862, p. 269 & pl. xxx, figs. 17–18.

approaches more nearly, perhaps, that distinguishing *L. pharaonis*; although the anterior side appears to be more compressed than in that species, and therefore it resembles Dr. Oppenheim's type, which was founded upon an internal cast from the Lower Eocene deposits of Egypt. The markings on the valves, both pallial and adductor, are fairly distinct, while parts of the surface exhibit concentric and radial striations; moreover, the left valve is minutely pitted, as shown in Oppenheim's figure.

Dimensions (with closed valves):—Length = 60 millimetres; height = 60 mm.; diameter = 30 mm.

Occurrence.—Specimen associated with a compact cream-coloured limestone weathering yellowish or light red, which appears to contain no *Nummulites*.

Locality.—Wadi, first camp, west of Derna.

CORBIS LAMELLOSA (Lamarck). (Pl. XLV, figs. 12 & 13.)

Lucina lamellosa Lamarck, Ann. Mus. Hist. Nat. (Paris) 1806 & 1808, vol. vii, p. 237, & vol. xii, pl. xlii, fig. 3.

Corbis lamellosa Schauroth, 'Verzeichniss Versteinerungen' 1865, p. 208.

Fimbria lamellosa Frauscher, Denkschr. K. Akad. Wiss. Wien, 1886, vol. li, pt. 2, p. 172.

Corbis lamellosa Cossmann, Ann. Soc. Roy. Malacol. Belg. 1887, vol. xxii, p. 15; Oppenheim, Palæontographica, 1903, vol. xxx, pt. 3, No. 1, p. 152.

Remarks.—The specimen referred to this species exhibits an external view of a fragmentary valve, attached to the matrix, having imperfect marginal terminations. It is probably a left valve—although this is uncertain, on account of the dorsal characters being very obscure. The sculpture is, however, important, as it resembles in every way that characterizing this well-known species. The equidistant, prominently concentric laminæ are well seen, together with the closely-arranged vertical striations which occur between them.

According to M. Cossmann, this shell ranges through all the stages of the Eocene formation. Schauroth has determined it from the Bartonian Beds of Ronca in Northern Italy, Frauscher has recognized it in the Lower Eocene deposits of the Northern Alps, while Oppenheim refers to its occurrence in the Mokattam Beds of Egypt. *Corbis pseudolamellosa* of the last-named author,[1] from the Priabonian formation of Northern Italy, shows also some striking resemblances to the specimen from Cyrenaica.

Occurrence.—In a cream-coloured limestone weathering reddish, associated with *Nummulites*.

Locality.—Near Slonta.

MACTRA cf. FOURTAUI Cossmann.

Mactra fourtaui Cossmann, Bull. Inst. Égyptien, 1901, p. 184 & pl. iii, figs. 18, 20; Oppenheim, Palæontographica, 1906, vol. xxx, pt. 3, No. 2, p. 189 & pl. xix, figs. 7–8.

Remarks.—This specimen, although only a cast, has much the

---

[1] P. Oppenheim, 'Rivista Italiana di Paleontologia' vol. vi (1900) p. 32 & pl. i, figs. 3–3 *a*.

contour of Cossmann's *M. fourtaui* from the Upper Mokattam Beds of the Fayûm. It represents a left valve with a nearly median umbo, and a prominent lunuloid cavity followed by a subrostration. From being a cast the surface is quite smooth, and therefore the concentric striations which characterize the original specimens and the further example figured by Dr. Oppenheim are absent.

Dimensions (left valve).—Length = 40 mm.; height = 30 mm.

Occurrence.—In a pale marly limestone with *Nummulites*.

Locality.—Near top of pass leaving Wadi Khumas.

CARDITA sp.

Remarks.—Specimen represented by a fragmentary natural cast in the matrix, exhibiting a portion of rather more than a dozen costæ belonging to a right valve. These costæ are well-elevated, narrow, equidistantly separated by deep channels which are of similar width to the ribs. Although no ornamentation is preserved, the costal system somewhat resembles that seen in *C. acuticostata* of Lamarck, from the Middle and Upper Eocene of France; but that shell has the summits of its costæ furnished with minute spinose serrations, which are now either lost or were never present in the fragment from Cyrenaica. Only costal characters are seen, neither umbonal nor other details of the shell being preserved.

Occurrence.—The specimen is associated with another pelecypod cast, nummulites, etc., in a cream-coloured marly rock, weathering light brown.

Locality.—Top of pass leaving Wadi Khumas.

VI. LUTETIAN.

The Lutetian formation and its fauna are so well known in Northern African countries, that it is needless to go into particulars respecting their history, and it is only necessary to refer the student to the Memoirs that have been issued by the officers of the Geological Survey of Egypt (Messrs. Beadnell, Hume, Barron, Ball, and others) for the last ten years, or to the monograph published by Dr. Blanckenhorn in 1900,[1] for full references to the chief literature on this subject.

The solitary shell which comes under this denomination is worthless as a specimen; but its matrix contains an important organism which enables us to determine the presence of Lutetian or Middle Eocene rocks in Cyrenaica.

This is one of the giant *Nummulites* known as *gizehensis* of Ehrenberg, but which belongs to the well-known *complanatus* type originally described by Lamarck, and is known throughout the Lutetian areas of Egypt, Palestine, and Syria, besides further regions of Northern Africa, and other Mediterranean countries

---

[1] Zeitschr. Deutsch. Geol. Gesellsch. vol. lii (1900) pp. 403–79.

such as Spain, Italy, etc., as well as Crete, where these large *Nummulites* were long ago determined by D'Archiac.[1]

The matrix containing this nummulite and oyster is much more compact than the sandy-looking rock that contains the pectiniform shells—regarded as of Aquitanian age: both deposits being similarly localized yet furnishing evidence of different horizons, Ain Sciahat being the neighbourhood referred to.

Pelecypoda.

OSTREA sp. indet.

Remarks.—The specimen is a fragmentary oblong, smooth and moderately convex valve, embedded in matrix, which has apparently lost, through erosion or otherwise, its external layers, so that only the polished surface of the inner structure of the shell is now exposed. It is not possible, therefore, to identify such a fossil, but from its general shape and very slight curvature of the postero-dorsal region, it might have belonged to such a form as Solander's *Ostrea gigantea*, which is distributed throughout the Eocene rocks.

Dimensions (approximate).—Length = 60 millimetres; height = 80 mm.

Occurrence.—The matrix is a cream-coloured limestone containing *Nummulites gizehensis*.

Locality.—Plateau above Ain Sciahat.

VII. RESULTS.

The fossil shell-remains from Cyrenaica prove the presence of post-Pliocene, Miocene (Vindobonian and Aquitanian), Oligocene or Uppermost Eocene (Priabonian), and Middle Eocene (Lutetian).

The post-Pliocene fauna is similar to what is known in other North African or Mediterranean countries, the presence of *Cerastoderma edule* in rocks situated some distance from the sea-board in a solid limestone suggesting a more ancient facies than those occurring in an actual beach-deposit nearer the sea.

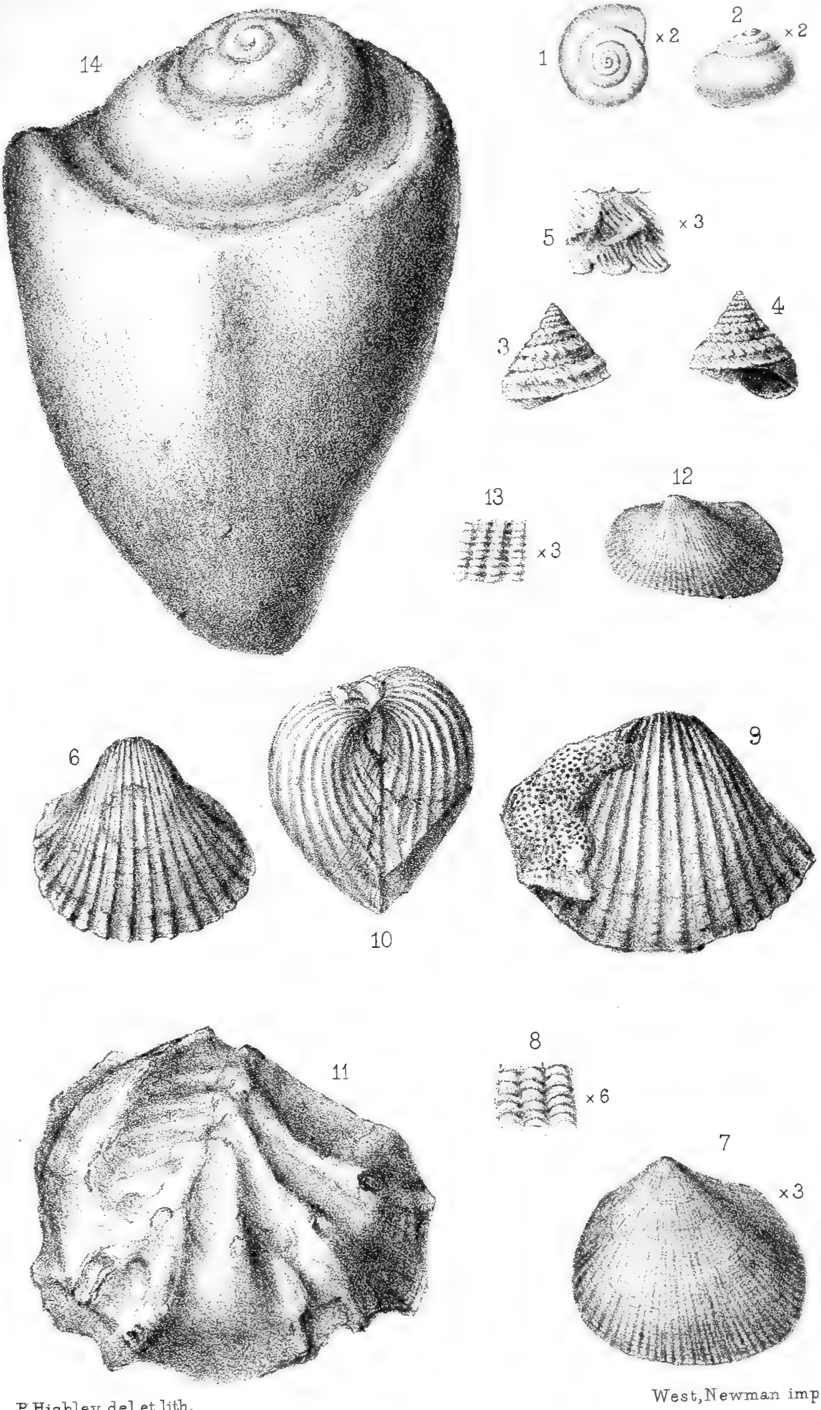
Such mollusca as *Strombus* cf. *coronatus*, *Alectryonia* cf. *virleti* constitute reliable evidence in favour of the Helvetian-Tortonian (Miocene) deposits being present in Cyrenaica, and forming part of similar beds occurring in Egypt and other neighbouring countries. The genera *Amphistegina* and *Lithothamnion* also occur in these rocks.

The abundant pectinoid shells found at Ain Sciahat with highly ornamented costæ, as well as the simpler forms found at Birlibah and Wadi Umzigga, favour an Aquitanian horizon, more especially as specimens from the last-named locality exhibit examples of *Lepidocyclina elephantina*, which is characteristic of Aquitanian deposits.

---

[1] See V. Raulin, 'Note sur la Constitution Géologique de l'Ile de Crète' Bull. Soc. Géol. France, ser. 2, vol. xiii (1856) pp. 439–58.

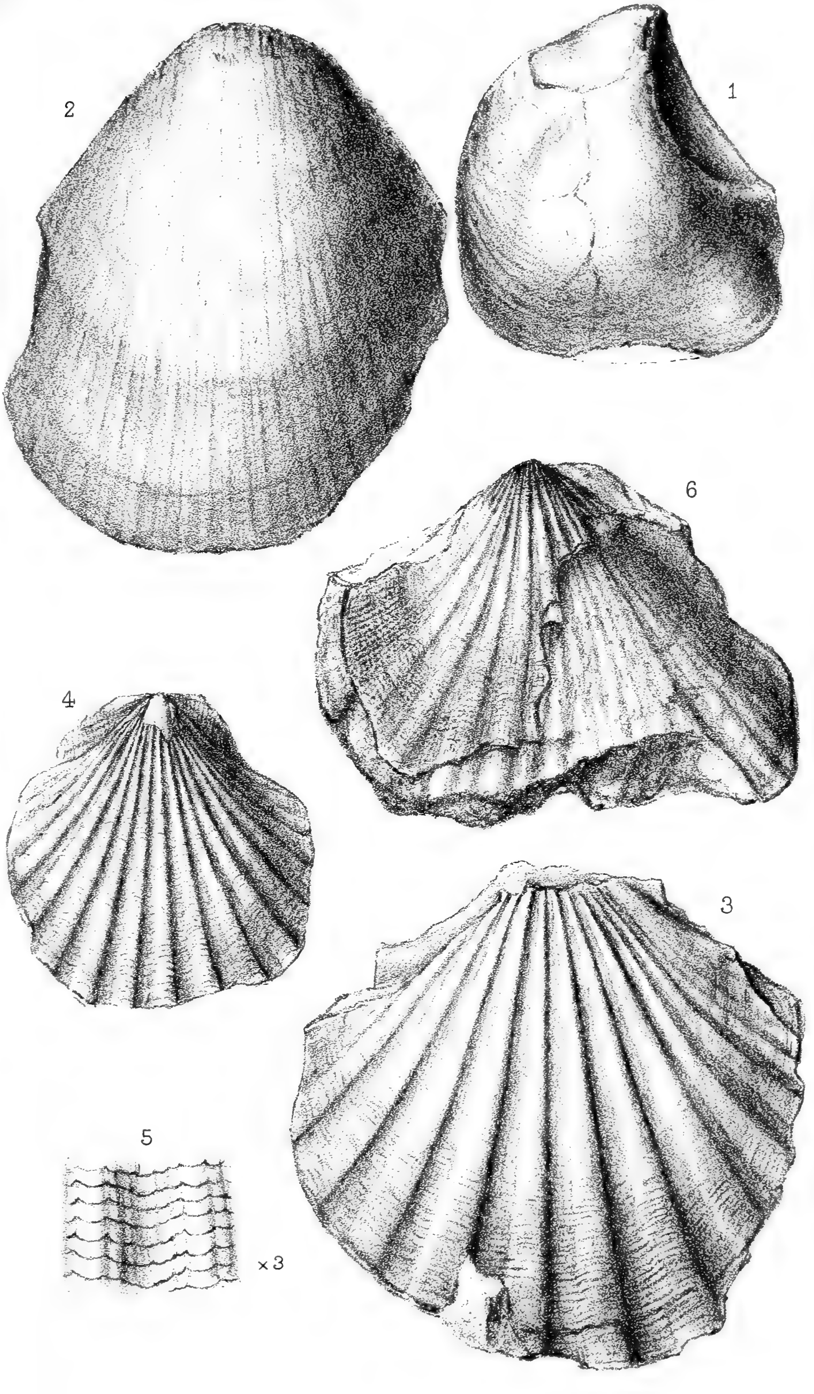
Quart. Journ. Geol. Soc. Vol. LXVII, Pl. XLIII.



P. Highley del. et lith.

West, Newman imp.

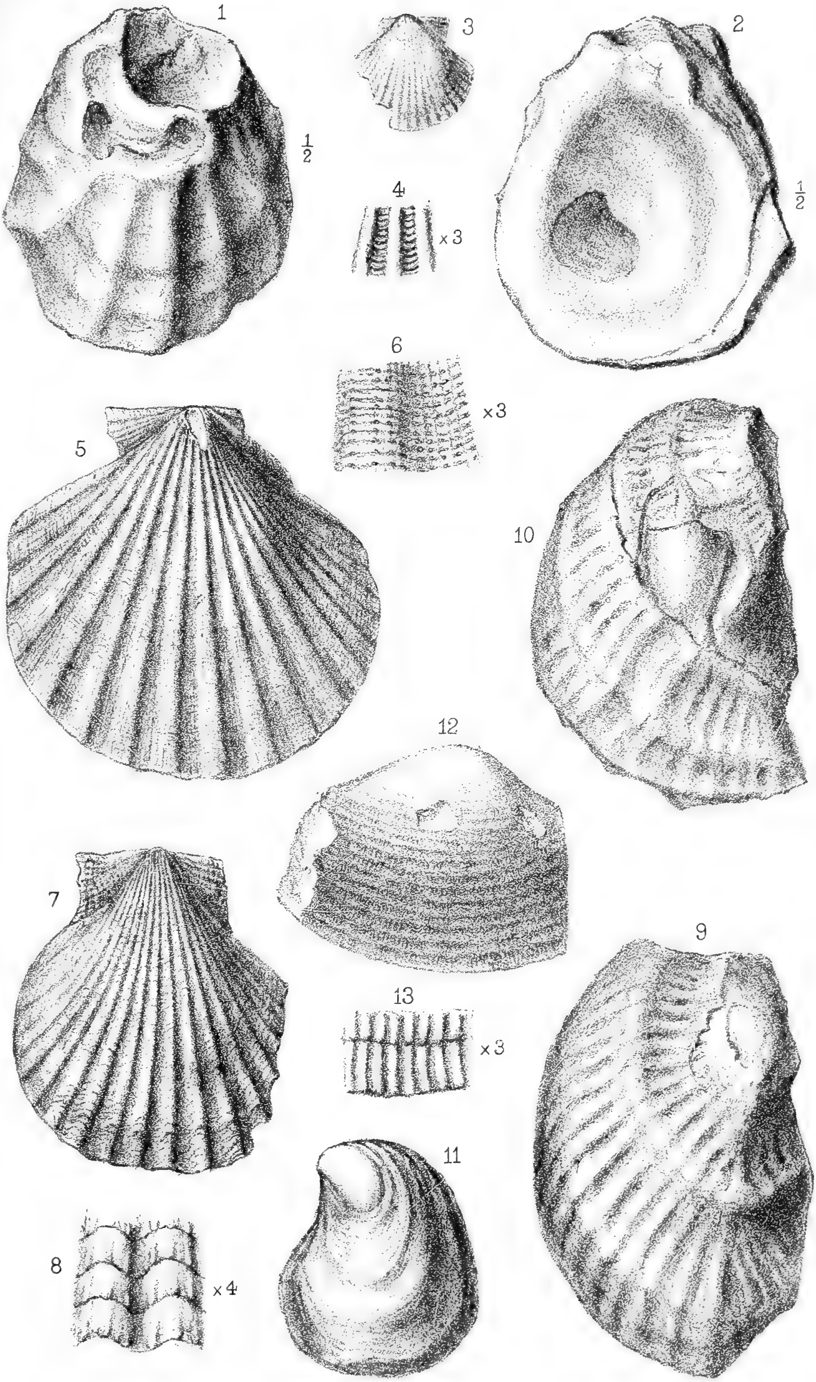
KAINOZOIC MOLLUSCA FROM CYRENAICA.
(Post-Pliocene & Vindobonian.)



P. Highley del. et lith.

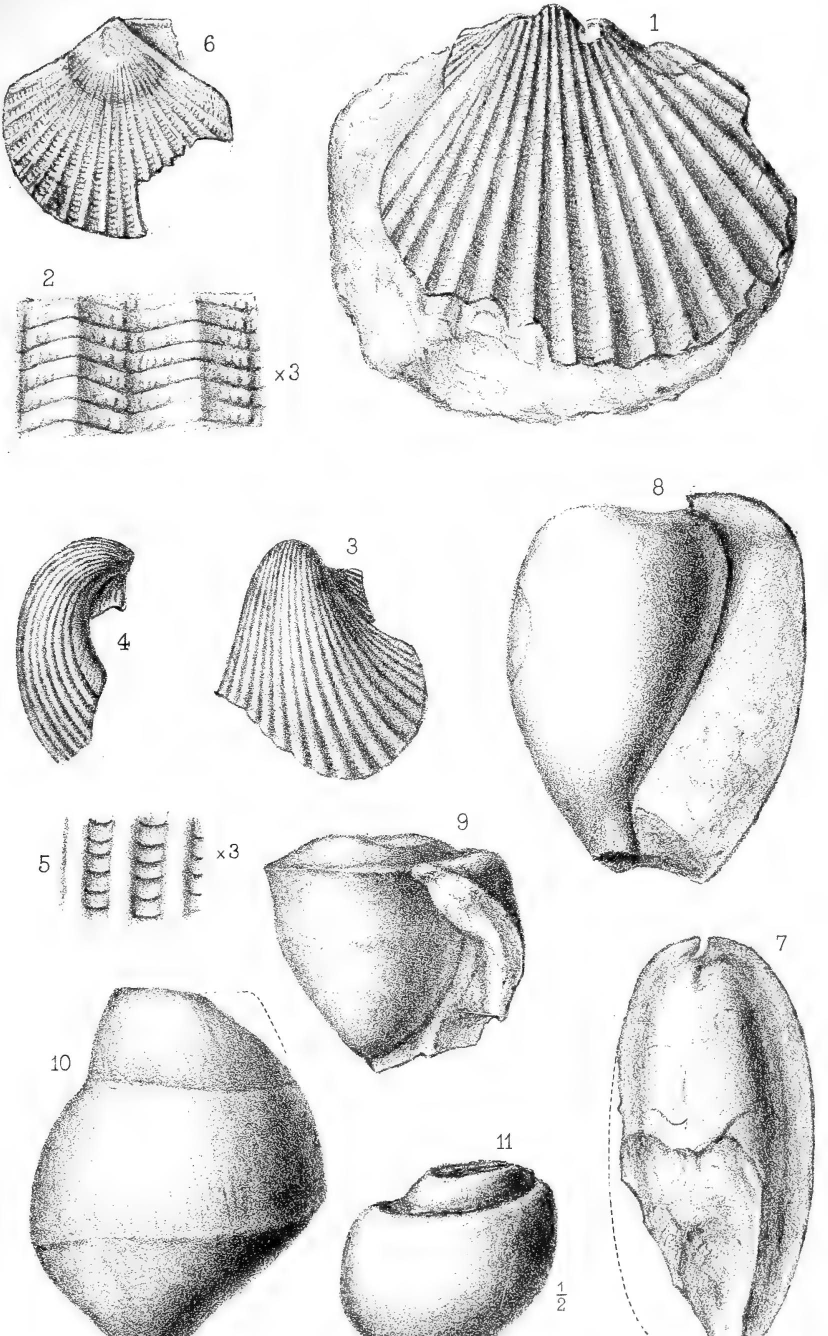
West, Newman imp.

KAINOZOIC MOLLUSCA FROM CYRENAICA.
(Aquitanian.)



P. Highley del. et lith.
West, Newman imp.

KAINOZOIC MOLLUSCA FROM CYRENAICA.
(Aquitanian & Priabonian)



P. Highley del. et lith.
West, Newman imp.

KAINOZOIC MOLLUSCA FROM CYRENAICA.
(Priabonian)

The occurrence of *Pecten arcuatus* and other associated mollusca would suggest the presence of the Priabonian horizon.

The late Prof. Rupert Jones's remark that the specimen of *Nummulites perforata* from Mersa Susa, one of the localities yielding *Pecten arcuatus* of the present collection, was found in rocks which were considered to be younger than the Nummulitic beds of Crete, the latter being regarded as of Lutetian or Middle Eocene age, is curious confirmation of the present results, the molluscan evidence now determining the Priabonian horizon for these particular deposits.

The presence of Lutetian or Middle Eocene beds in Cyrenaica seems also to be substantiated by the occurrence of the large *gizehensis* type of *Nummulites* found associated in the matrix with an indeterminable *Ostrea*.

A collection of well-preserved echinoids was also obtained from the various formations in Cyrenaica, and they have been studied by Prof. Gregory, with the general conclusion that their horizons agree with those now suggested for the Mollusca.

EXPLANATION OF PLATES XLIII–XLVI.

[Except where otherwise specified, the figures are drawn of the natural size.]

Plate XLIII.

Hygromia sordulenta (Morelet).

Post-Pliocene (recent beds). Bonmansur, south of Derna. (See p. 619.)

Fig. 1. The upper or spiral view. × 2.
2. Profile of the same specimen. × 2.

Helicella tuberculosa (Conrad).

Post-Pliocene (recent beds). Plain east of Benghazi. (See p. 620.)

Fig. 3. Dorsal aspect of the largest specimen.
4. Front view of the same.
5. Sculpture as seen on the penultimate whorl. × 3.

Cerastoderma edule (Linnæus).

Post-Pliocene (recent beds). Benghazi. (See p. 621.)

Fig. 6. External view of a left valve.

Jagonia pecten (Lamarck).

Post-Pliocene (recent beds). Benghazi. (See p. 622.)

Fig. 7. External view of a left valve. × 3.
8. Sculpture details of the same. × 6.

Cerastoderma edule (Linnæus).

Post-Pliocene (ancient beds). Plain east of Benghazi. (See p. 623.)

Fig. 9. Left lateral view of a specimen covered anteriorly by a limestone which is superficially pitted with minute rounded contiguous excavations of probably organic origin.
10. Posterior end or 'escutcheon view' of the same specimen.

Alectryonia cf. *plicatula* (Gmelin).

Miocene (Helvetian-Tortonian). Gubah. (See p. 626.)

Fig. 11. External view of a lower valve, showing the tubular character of the plications.

Anadara cf. *turonica* (Dujardin).

Miocene (Helvetian-Tortonian). From Merj Plain to Wadi Hamema.

Fig. 12. Outer aspect of a left valve. } See p. 628.
13. Surface-structure. × 3.

Strombus cf. *coronatus* Defrance.

Miocene (Helvetian-Tortonian). Gubah.

Fig. 14. Dorsal view of natural cast. (See p. 626.)

PLATE XLIV.

Ostrea cf. *caudata* Münster. (See p. 629.)

Miocene (Aquitanian). East of shrine of Sidi Mahomet Mahridi, east of Slonta.

Fig. 1. External view of a lower valve, showing attachment-surface.

Spondylus cisalpinus Brongniart.

Miocene (Aquitanian). Ain Sciahat (above camp). (See p. 630.)

Fig. 2. External view of specimen, showing the surface of the larger valve.

Oopecten rotundatus (Lamarck).

Miocene (Aquitanian). Wadi Umzigga. (See p. 634.)

Fig. 3. External view of a valve with an imperfect apical region.

Æquipecten cf. *pasinii* (Meneghini).

Miocene (Aquitanian). Ain Sciahat (above camp). (See p. 632.)

Fig. 4. Outer view of a left valve.
5. Portion showing details of sculpture. × 3.

Æquipecten haueri (Michelotti).

Miocene (Aquitanian). Birlibah. (See p. 634.)

Fig. 6. External view of a fragmentary valve.

PLATE XLV.

Ostrea crassicostata G. B. Sowerby. (See p. 630.)

Miocene (Aquitanian). East of shrine of Sidi Mahomet Mahridi, east of Slonta.

Fig. 1. External view of a lower valve, half the natural size.
2. Inner view of same specimen, half the natural size.

Pecten vezzanensis Oppenheim.

Miocene (Aquitanian). Ain Sciahat. (See p. 631.)

Fig. 3. External view of specimen.
4. Sculpture details of the same. × 3.

Æquipecten camaretensis (Fontannes). (See p. 633.)

Miocene (Aquitanian). Fountain of Apollo, Cyrene. [B.M.—L 16341.]

Fig. 5. View of a well-preserved valve.
6. Sculpture details of the same. × 3.

Æquipecten zitteli (Fuchs).

Miocene (Aquitanian). Ain Sciahat. (See p. 632.)

Fig. 7. External view of a specimen.
8. Sculpture details of the same. × 4.

Ostrea ventilabrum Goldfuss.

Oligocene or Eocene (Priabonian). Near Slonta. (See p. 642.)

Fig. 9. A spreading and depressed form of a lower valve.
10. Another specimen, showing a more arcuate character.
11. An upper valve belonging to a small specimen.

Corbis lamellosa (Lamarck).

Oligocene or Eocene (Priabonian). Near Slonta. (See p. 648.)

Fig. 12. External view of a fragmentary valve.
13. Sculpture of the same specimen, showing the characteristic vertical costæ between the concentric ribs. × 3.

PLATE XLVI.

Æquipecten cyrenaicus, sp. nov.

Oligocene or Eocene (Priabonian). Ain Sciahat (above camp). (See p. 644.)

Fig. 1. External view of a specimen representing a lower or right valve, showing the V-shaped furrows.
2. Sculpture details of the same. × 3.

Pecten arcuatus (Brocchi).

Oligocene or Eocene (Priabonian). Messa, and near Bint. (See p. 643.)

Fig. 3. Outer aspect of a fragmentary lower valve from Messa.
4. Profile of the same, showing convexity.
5. Sculpture details of the same specimen. × 3.
6. External view of an upper valve of another specimen, from near Bint.

Vulsella sp.

Oligocene or Eocene (Priabonian). South-east of Merj. (See p. 645.)

Fig. 7. Valve of lingulate contour, resembling *V. crispata* Fischer.

Gisortia gigantea (Münster).

Oligocene or Eocene (Priabonian). Mersa Susa. (See p. 640.)

Fig. 8. Front aspect of a small form in the condition of a natural cast.

Vasum cf. *frequens* (Mayer-Eymar).

Oligocene or Eocene (Priabonian). Messa. (See p. 641.)

Fig. 9. Front aspect of a specimen (natural cast), showing traces of columellar plications. Reduced to half the natural size.

Rostellaria sp.

Oligocene or Eocene (Priabonian). South-east of Messa. (See p. 640.)

Fig. 10. Dorsal view of a limestone cast.

Euspira cf. *possagnensis* Oppenheim.

Oligocene or Eocene (Priabonian). East of Ain Hafra. (See p. 638.)

Fig. 11. Dorsal view of a natural cast, showing the extensive basal whorl. Reduced to half the natural size.

(C) FORAMINIFERA, OSTRACODA, *and* PARASITIC FUNGI *from the* KAINOZOIC LIMESTONES *of* CYRENAICA. By FREDERICK CHAPMAN, A.L.S., F.R.M.S.

THE following report is based on specimens collected by Prof. J. W. Gregory in Cyrenaica. The principal localities whence the samples came are Derna on the coast, a camp about 5 miles west of Derna, and Ain Sciahat, the site of the ancient city of Cyrene, which is about 2000 feet above sea-level. The specimens range in age from Middle or Lower Eocene to Pleistocene.

Previous Literature.

The only necessary reference to literature is the following extract from the late Prof. T. Rupert Jones's 'Catalogue of Fossil Foraminifera in the British Museum' (1882, p. 45):—

> '*Nummulites perforata.* Marsa Susa, the ancient port of Cyrene. From strata younger than the Nummulitic bed of Crete referred to further on [p. 48]. Collected by Admiral Spratt.'

Details of the Rock-Samples.

Derna.

The specimens from Derna include a consolidated beach-sand with some molluscan shells. This rock is mainly composed of small rolled shell-fragments, which have been cemented by carbonate of lime into a fairly coherent rock.

Horizon.—Pleistocene.

Two specimens collected from the Wadi Derna near the town are pink or cream-coloured nummulitic limestones, having the nummulites exquisitely preserved, and showing the structure in median sections in a most striking manner. Most of the chambers of these discoidal foraminifera are empty, and the septation is thus clearly shown up to the centre of the test. These nummulites vary from 1·5 to 4 millimetres in diameter. The surface is distinctly striate. The central chamber is a megasphere, and in full-sized individuals there are about five whorls of chambers. They all belong to *N.* (*Paronia*) *curvispira* Meneghini, a companion-form to the large microspheric *Nummulites gizehensis* Ehrenberg.

Horizon.—Middle Eocene.

'Derna' (No. 178). A large test of *Nummulites gizehensis* Ehr. measuring 5·8 cm. in diameter and 7 mm. in greatest thickness. Some limestone-matrix attached to the specimen carries a few tests of *N. rouaulti* d'Arch., a form closely allied to *N. curvispira*, but distinguished by its sharp periphery and greater umbilical axis.

Horizon.—Middle Eocene.

'Derna' (Nos. 177, 179–181). Nummulitic limestones with *N. gizehensis* Ehr., *N. curvispira* Menegh., and *N. rouaulti* d'Arch.

Horizon.—Middle Eocene.

'Ain Seghia—Wadi Derna' (No. 22). A pink limestone with large and well-preserved individuals of *Nummulites ehrenbergi* De la Harpe, and *N. curvispira* Menegh. The former measures nearly 5 centimetres in diameter.

Horizon.—Middle Eocene.

'Foraminiferal limestone about 340 feet above sea-level, above Bint, east of Derna' (No. 28). A pale yellowish limestone, somewhat friable, containing numerous small organisms, chiefly foraminifera. A crushed sample yielded the following species :—

Miliolina contorta (d'Orb.). Several specimens.
M. lucens Schwager. Numerous.
M. ferussaci (d'Orb.). One minute example with few, neat coils.
Polymorphina compressa d'Orb.
Truncatulina culter (P. & J.).
Tr. lobatula (W. & J.).
Tr. ungeriana (d'Orb.). Recorded from the Middle Eocene (Mokattam Marl), near Cairo, by Schwager, under the name of *Pulvinulina mokattamensis*.
Anomalina ammonoides (Reuss).
A. insecta Schwager.
Pulvinulina repanda (F. & M.).
P. elegans (d'Orb.).
Polystomella striatopunctata (F. & M.).
Operculina libyca Schwager.
Nummulites curvispira Menegh.

Horizon.—Middle Eocene.

'Wadi Nagr, first camp west of Derna' (No. 39). A white, somewhat chalky limestone, containing abundant, more or less fragmentary tests of *Orthophragmina pratti* (Mich.) [see Notes, p. 659]. *Operculina* and *Nummulites*, with numerous echinoid-fragments, are also present.

Horizon.—Bartonian (Upper Eocene) or Lutetian (Middle Eocene).

'Slope above Camp at Wadi Nagr, Derna' (No. 44). A pink limestone, composed of *Lithothamnion* and foraminifera. In thin section this rock is seen to consist of numerous fragments of a thick shrubby *Lithothamnion*, with an equal proportion of tests of nummulites, chiefly *N. curvispira* ; also tests of smaller foraminifera such as *Truncatulina*, and fragments of echinoid-tests and spines, embedded in a subcrystalline matrix. The pieces of *Lithothamnion* are invariably more or less crowded with small, stout, rhombic dolomite-crystals, often showing a dark centre and zonal structure.

Horizon.—Middle Eocene.

Wadi Umzigga.

'Limestone with *Oopecten*; Wadi Umzigga' (No. 41). A weathered limestone-fragment consisting almost entirely of the tests of *Lepidocyclina elephantina* Munier-Chalmas (see Notes, p. 660). A few rotaline foraminifera are seen scattered through the matrix, and also some tubular remains of (?) calcareous algæ.

Horizon.—Aquitanian (Lower Miocene) or Stampian (Upper Oligocene). This horizon is given on the excellent authority of M. Douvillé.

The District of Cyrene.

'Limestone with echinoid spines, etc.; Sidi Rof Diasiasia, south-east of Cyrene.' A pale cream-coloured limestone weathering to pink; composed of echinoid-spines and test-plates, and foraminifera, chiefly nummulites. A slender flexuous variety of *N. gizehensis*, var. *viquesneli* De la Harpe, is here common. Also several specimens of *Operculina* cf. *libyca* Schwager.

Horizon.—Lower Eocene to Miocene.

'Limestone; coastal plain west of Mersa Susa' (No. 92). A dense, cream-coloured nummulitic limestone weathering to a reddish colour. The nummulites are beautifully preserved; they are chiefly *N. gizehensis* Ehr. and *N. curvispira* Menegh. There also occurs a very fine median section of a minute nummulite, *N. subbeaumonti* De la Harpe.

Horizon.—Middle Eocene.

'Foraminiferal limestone, 530 feet above the sea, west of Mersa Susa' (No. 95). A dense, cream-coloured limestone, showing cleavage-surfaces of echinoid-plates and spines. A microscopic section reveals a purely organic base of minute foraminifera, calcareous algæ, and shell-fragments, through which are scattered nummulites and echinoid-remains. The nummulites are comparatively small, thick, and possess a bluntly rounded periphery. They are, in all probability, referable to *N. subdiscorbina.*

Horizon.—Middle Eocene.

'Echinoid-limestone; 1100 feet above the sea. Platform east of Ain Hafra' (No. 98). A hard, cream-coloured limestone, with ferruginous weathering and many natural sections of *Nummulites subdiscorbina* De la Harpe. A similar rock at the level of 1090 feet, north of Cyrene, includes *N. subramondi* De la Harpe.

Horizon.—Middle Eocene.

'*Fibularia* Limestone. Altitude 1215 feet above sea-level. Foot of Upper Cliff of Cyrene, west of Ain Hafra' (No. 78). Limestone with echinoid-remains, and a small species of *Nummulites*, cf. *N. curvispira.*

Horizon.—(?) Middle Eocene.

N. gizehensis var. *lyelli*, associated with *N. curvispira* Menegh., occurs in specimens Nos. Cy 84, Cy 86, Cy 88, from the Cyrene escarpment north of Ain Sciahat, at the level of 1560 feet and a little below that.

Horizon.—Middle Eocene.

'Marly limestone with *Clypeaster*. East of camp at Ain Sciahat' (No. 187).—A calcareous marl, containing numerous tests of *Operculina libyca* Schwager. A similar marl from above the camp at Ain Sciahat (No. 188) is full of *Nummulites subramondi* De la Harpe.

Horizon.—Lower Eocene to Miocene.

This specimen also yielded *Bolivina textilarioides* Reuss, and *Pulvinulina karsteni* Reuss.

The Slonta District.

'Nummulitic limestone, about 5 miles north-east of the shrine of Sidi Mahomet el Homra, east of Slonta.' A compact limestone variously coloured, from pale cream on the fresh surface, to reddish brown on the weathered portions. The rock is largely composed of nummulites, chiefly *N. gizehensis* var. *pachoi* De la Harpe, and *N. curvispira* Meneghini.

Horizon.—Middle Eocene.

'A brecciated shell-limestone east of Slonta' (No. 289), with numerous foraminifera, chiefly *N. subdiscorbina*, De la Harpe.

Horizon.—Middle Eocene.

Echinolampas Limestone (No. 290), north of the Roman Castle, north-west of Slonta, and an iron-stained limestone (No. 288), east of Slonta, are both chiefly composed of *Nummulites gizehensis* var. *lyelli* and *N. curvispira.*

Horizon.—Middle Eocene.

Messa and Wadi Jeraib.

'A yellow limestone (No. 239), with *Pecten arcuatus*,' Messa, is composed of a small lenticular nummulite. The form and arrangement of the septa, the number of whorls, and the shape and size of the small central chamber, all point to the species as belonging to the '*planulata*' group. De la Harpe regarded Lamarck's species *N. planulata* as divisible into *N. planulata sensu stricto* and *N. elegans* Sow., and made a third species, *N. fraasi*, distinguished by its smaller size as compared with the typical microspheric *N. planulata*: in that feature it also resembles the megalospheric shell of *N. elegans.* The present form may, therefore, be regarded as a moderately small variety of De la Harpe's *N. fraasi.* The typical examples of the latter occur in Egypt, according to De la Harpe,[1] in the Libyan Stage (Lower Eocene) of El Guss Abu Said, west of Farafrah. In the Nummulitic series of Sinai, from a bed referred either to Middle or to Upper Eocene, I have recorded undoubted examples of *N. planulata.*[2] It is, therefore, possible that the small variety from Messa is one of the remnant of the *planulata* type, which ranged upwards as far as the Bartonian. The Cyrenean specimens average 2 millimetres in diameter, and show four to five whorls in transverse section; they have about six chambers in a quadrant on the fourth whorl.

'Limestone. Gasr el Migdum' (No. 189).—A hard, compact, whitish limestone, crowded with well-preserved tests of *Nummulites beaumonti* D'Archiac.

Horizon.—Middle Eocene.

---

[1] Palæontographica, vol. xxx, pt. 1 (1883) p. 162 [8].

[2] Geol. Mag. dec. 4, vol. vii (1900) pp. 367–68.

The District near Merj.

'Limestone south-west of Bigratah, north-east of Merj' (No. 140). This specimen has been discoloured to an ashen grey. The weathered surface is ironstained, and shows numerous sections of *Nummulites gizehensis* and *N. curvispira*.
Horizon.—Middle Eocene.

'Nummulitic limestone, north-eastern end of the Merj plain.'—A dense cream-coloured limestone, weathering to a ferruginous red. The weathered surface shows etched tests of *N. gizehensis* (*typica*).
Horizon.—Middle Eocene.

'Limestone with *Echinolampas*. Wells at Merj' (No. 134).—Two specimens of a nummulitic limestone which is red on the weathered surface. Containing tests of *Nummulites gizehensis* var. *lyelli* and *N. curvispira*.
Horizon.—Middle Eocene.

'Nummulitic limestone at the top of the plateau-scarp, south-east of Merj' (No. 164). A dense, white nummulitic limestone, showing cleavage-surfaces of echinoid-plates on the fractured faces of the rock. In microscope-section the rock is seen to be partly recrystallized, the matrix being finely crystalline, and the cavities of the organisms in part filled with larger crystals of calcite. Organisms rather obscure. The following genera of foraminifera are present:—*Sigmoïlina*, *Alveolina*, *Anomalina*, and *Nummulites*.

'Oolitic limestone. Altitude 440 feet above sea-level, on the scarp west of Ptolemeta' (No. 156).—A loosely consolidated beach- or dune-sand, consisting of rolled fragments of shells, *Lithothamnion* and foraminifera (*Miliolinæ* of the *M. trigonula* and other shallow-water types), cemented together by a thin layer of calcareous material. All the fragmentary constituents are calcareous and of organic origin, and are bored in all directions by a perforating organism. This rock resembles the Kathiawar building-stone.[1]

East of Benghazi.

'Limestone. Plain east of Benghazi' (No. 183). An extremely hard, fine-grained limestone, containing shells of gasteropods entirely recrystallized. Under the microscope this rock is seen to be a fine calcareous mud containing echinoid-spines, and foraminifera (*Dentalina* and *Globigerina*). The rock is brecciated, and in one fragment is a cluster of radiolarian tests, rather poorly preserved. A specimen (No. 185) from an adjacent locality is largely composed of fragments of *Lithothamnion*, and is in part dolomitized.

---

[1] See Q. J. G. S. vol. lvi (1900) pl. xxxii, fig. 2.

Notes on the Fossils.

Parasitic (?) Fungi.

PALÆACHLYA sp.

The tests of *Lepidocyclina elephantina* Munier-Chalmas, which form the bulk of rock-specimen No. 41 from Wadi Umzigga, are seen in thin section under a high power to be in parts permeated by a perforating fungus, which closely resembles *Palæachlya perforans* Duncan.[1] The spores are 17μ in diameter, consisting of a dark-brown nucleus and a transparent, yellowish investment, and they are roughly spherical. They run in strings of six or more, crossing one another, and so forming an open network. The thread-like hyphæ form a densely-matted structure, occurring in patches through much of the test-wall of the foraminifer. These spores remind one of many similar occurrences in the tests of Tertiary foraminifera, noted by Carter and others. The brown colour of the nucleus is probably the result of the reaction of organic agencies, such as ulmic acid, on the iron of the accompanying sediments.

Foraminifera.

NUMMULITES CURVISPIRA Meneghini, var. MAJOR, nov.

The nummulites in specimen No. 88, referable to *N. curvispira*, possess an extraordinarily large megasphere. Its usual diameter in that species and in the related *N. tchihatcheffi* D'Arch. is about 1 mm. Our specimens further differ from *N. tchihatcheffi*, which has a rounded periphery, by being sub-acute on the margins.

The diameter of the megasphere in the variety *major* is 1·75 mm.

ORTHOPHRAGMINA PRATTI (Michelin).

Orbitolites prattii Michelin, 1846, 'Iconographie Zoophyt.' p. 278 & pl. lxiii, fig. 14.
Orbitolites fortisii D'Archiac, 1850, Mém. Soc. Géol. France, ser. 2, vol. iii, p. 404 & pl. viii, figs. 10–12.
Orbitoides (Discocyclina) papyracea Gümbel (*non* Boubée), 1868, Abhandl. K. Bayer. Akad. Wissensch. vol. x, p. 690 & pl. iii, figs. 3–12, 19–29.
Orthophragmina pratti (Michelin) Schlumberger, 1903, Bull. Soc. Géol. France, ser. 4, vol. iii, p. 274, pl. viii, figs. 1–3, 8–10, pl. ix, fig. 17 & text-figs. *a*, *b*.

This is a well-known type of the older or Eocene group of *Orbitoides*, some of the tests in the rock from Derna (No. 39) having a diameter of 17 mm. They are somewhat flexuose, and thus bear a certain resemblance to *Orthophragmina sella* (D'Arch.) = *O. ephippium* (Schlotheim), but are not so remarkably saddle-shaped as that species. I have not, so far, succeeded in cutting through the initial series of chambers in the present specimens; but the thickness of the median series of chambers in vertical

---

[1] Q. J. G. S. vol. xxxii (1876) p. 205 & pl. xvi.

section, and the character of the pillars in the outer layer, sufficiently determine the species. The present specimens are only of moderate dimensions, since D'Archiac recorded this form as having a diameter as great as 50 mm. The average length of the chambers in the present examples is ·125 mm.; width of ditto = ·025 mm.

O. pratti occurs typically at Kressenberg (Middle Eocene) and Biarritz (Upper Eocene).

LEPIDOCYCLINA ELEPHANTINA Munier-Chalmas.

L. elephantina Munier-Chalmas, 1891, 'Étude du Tithonique, du Cretacé & du Tertiaire du Vicentin, Thèse de Doctorat': Paris, pp. 71-77, 90; Prel. Note (Bull. Soc. Géol. France, ser. 3, vol. xix, p. xxxii). See also P. Lemoine & R. Douvillé, 1904, Mém. Soc. Géol. France, vol. xii, no. 32, fasc. ii, p. 13 & pl. ii, figs. 13, 19.

A limestone (No. 41) from the Wadi Umzigga consists almost wholly of the agglomerated tests of this species, which is the largest known *Lepidocyclina*. It reaches a diameter of 8 to 10 cm., according to MM. Lemoine & Douvillé. It is closely allied to *L. dilatata* Michelotti, an Aquitanian species which, however, in the microspheric stage, or form with the larger test, attains a diameter of only 4 centimetres.

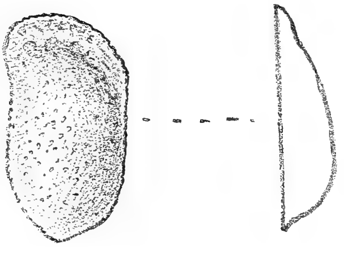
One fragment in a thin section shows a megasphere which measures about 1·37 mm. in diameter; the thickness of the intermediate area of the test is about 65 mm. On the authority of Lemoine & R. Douvillé[1] (1904), *L. elephantina* is typical of Aquitanian beds in Italy: while H. Douvillé[2] holds that the species is Stampian (Upper Oligocene).

Ostracoda.

LOXOCONCHA CYRENAICA sp. nov.

Description.—Valves in side view, subquadrate; anterior border rounded below and obliquely truncate above; posterior extremity bluntly acuminate; ventral border sinuous, and convex in the posterior third; dorsal border nearly straight. Edge view, subtrigonal, thickest in the posterior third, sloping evenly towards the anterior edge. Surface of the valves covered with fine prickles; the sulcus behind the anterior margin is relieved by a few large pits, with evidence of less conspicuous pits along the extreme anterior margin.

Loxoconcha cyrenaica, *sp. nov.* × *40.*



[No. 28 from near Bint, east of Derna, Middle Eocene.]

---

[1] Mém. Soc. Géol. France, vol. xii, fasc. ii, No. 32, p. 31.

[2] Bull. Soc. Géol. France, ser. 4, vol. vii (1907) p. 468.

Length = ·725 millimetre; height = ·4 mm.; thickness of carapace = ·325 mm.

Remarks.—The carapace of this species is somewhat like that of *L. tamarindus* (Jones),[1] in outline, viewed from the side; but the form here described is much thicker posteriorly, and has the anterior border distinctly acuminate.

Horizon.—Middle Eocene at Wadi Nagr, west of Derna (No. 33). In a compact subcrystalline limestone, slightly iron-stained; mainly composed of the large tests of *Nummulites gizehensis* Ehr. (one having a diameter of 5·5 centimetres), and *N. curvispira* Menegh.

CYTHERE STRIATOPUNCTATA (Römer).

Frequent. A common species in the Middle Eocene of England and the continent of Europe.

Horizon.—Middle Eocene. Wadi Nagr, west of Derna (on No. 33).

? CYTHERE WETHERELLI Jones.

One valve in a marly limestone (No. 187), from east of Ain Sciahat, which contains *Operculina libyca* Schwager, *Bolivina textilarioides* Reuss, and *Pulvinulina karsteni* Reuss. It belongs doubtfully to the genus *Cythere*, and resembles *Cythere wetherelli* Jones[2] in many respects, although it is not quite identical. The latter form is found in the Upper Eocene and Oligocene of Colwell Bay and the Upper Eocene of Barton. Also in the Antwerp Crag (Lower Pliocene).

(D) *The* FOSSIL ECHINOIDEA *of* CYRENAICA. By JOHN WALTER GREGORY, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

[PLATES XLVII–XLIX.]

THE specimens were collected during the expedition of which the geological results have been recorded in the foregoing pages (572–615). The fossil Echinoidea collected in Cyrenaica during our journey include ten determinable species represented by over a hundred specimens. Many of them are imperfect, but were collected on account of the light which they might throw on the distribution of the species.

I have to express my thanks to Dr. F. A. Bather for having kindly compared some of the specimens of *Echinolampas* with specimens in the British Museum collection, and to M. J. Lambert

---

[1] *Cytherideis tamarindus* Jones, 'Monogr. Brit. Tert. Entom.' (Pal. Soc.) 1857, p. 49 & pl. iii, figs. 4*a*–4*b*; *Loxoconcha tamarindus* (Jones) G. S. Brady, Trans. Linn. Soc. vol. xxvi (1868) p. 435 & pl. xxv, figs. 45–48.

[2] Q. J. G. S. vol. x (1854) p. 161 & pl. iii, figs. 9*a*–9*b*.

for his careful examination of several of the species, as also for his valuable notes concerning their affinities.

The list of the chief echinoids collected is as follows:—

Clypeaster biarritzensis Cott.,
  var. *trotteri* nov.
Fibularia luciani (Lor,).
Scutella tenera Laube.
Amphiope duffi, sp. nov.
Amphiope sp.
Echinolampas cherichirensis Gauth.
Echinolampas discus Desor.
Hypsoclypeus hemisphericus (Greg.)
Hemiaster scillæ Wright.
Schizaster ederi, sp. nov.
Sarsella lamberti, sp. nov.
Euspatangus sp.

Description of the Species.

CLYPEASTER BIARRITZENSIS Cotteau, 1873, var. **TROTTERI** nov.[1] (Pl. XLVII, figs. 1 *a* & 1 *b*.)

Clypeaster biarritzensis Cotteau, 1873, in R. de Bouillé, 'Pal. Biarritz,' p. 10. [Not seen.]
Clypeaster biarritzensis Cotteau, 1891, 'Éch. Éoc., Pal. franç.: Terr. Tert.' vol. ii, p. 228 & pl. cclx.
Clypeaster biarritzensis Flick, 1900, 'Priab. en Tunisie' C. R. Acad. Sci. Paris, vol. cxxx, p. 149.
Clypeaster biarritzensis Pervinquière, 1903, 'Géol. Tunisie-Centrale' Carte Géol. Tunisie, p. 199.

Characters.—Form and dimensions similar to those normal to the species. Petals of ambulacra shorter, the poriferous zones broader, and the distal ends less open than in the typical form.

Dimensions in millimetres.	Cy 98.	*C. biarritzensis.* Cotteau's fig.	*C. breunigi.*		*C. subplacunarius.* Fuchs's type.
			Laube's type.	E. of Siwa.	
Length	70	66	46	60	91
Breadth	67·5	59	41	50	88
Height	11	9	10·5	11	12
Length of anterior petal	19·5	21	13·5	16·5	length=not quite two-thirds of the radius.
Distance from proximal end of anterior petal to anterior margin of test	34	31	22	24	

Distribution.—Typical form: Upper Eocene; Lou Cout near Biarritz. Gebel Batene, Tunisia.

Var. *trotteri*. In a pale-yellowish marly limestone containing many specimens of *Operculina libyca*. Half a mile east of the camp at Ain Sciahat, Cyrene (Cy 98).

Cy 273. Ain Sciahat, in a soft marly *Operculina* Limestone.

---

[1] The variety is named after my companion, Dr. J. Trotter, who collected one of the two specimens.

Affinities.—This Cyrenean *Clypeaster* agrees so closely in all characters, except the form and length of the petals, with *Cl. biarritzensis*, that it seems wiser to leave it in that species, but as a distinct variety.

As *Cl. biarritzensis* has not been recorded from Egypt, it was natural first to compare the specimens with the flat Upper Eocene *Clypeaster breunigi* of Laube, which agrees in general shape and has been recorded from the district east of Siwa. *C. breunigi* is either a very variable species, or else too many echinoids have been referred to it. The two specimens from Cyrene differ from Laube's type of *Cl. breunigi* in the absence of the vertical undulation of the margin of the test; but that character is not shown in the specimens from east of Siwa, or from Sta. Giustina near Possagno, referred to *Cl. breunigi* by P. de Loriol[1] and Dr. Oppenheim[2] respectively. De Loriol's specimens also differ from Laube's type in the character of the petals, which the former described as 'am Ende gerundet und weit offen'; and Laube also says that the petals are 'vorne weit offen,' but his figures represent them as nearly closed. Dr. Oppenheim's specimen, on the other hand, is a long oval echinoid, with short and nearly closed petals. It is only 30 mm. long, and so may be a young form: but he[3] suggests that it is a *Laganum*.

It seems to me very doubtful whether Laube's, P. de Loriol's, and Oppenheim's varieties can all remain in one species. They at least require distinction as well-marked varieties, as follows:—

1. Var. *typica* of Laube. Form pentagonal; apex blunt, and slopes leading to it convex; margin thickened and undulating vertically; petals long. (Character of outer ends of petals uncertain.)
2. Var. *lorioli* nov.; based on P. de Loriol's type. Form pentagonal; apex as a well-raised point, with slopes leading to it concave; margin thin and flat; petals long and open at their outer end.
3. Var. *oppenheimi* nov. or sp. nov.; based on Dr. Oppenheim's type. Test small; form oval; margin apparently thickened, but flat; summit blunt; petals short and closed. This form is probably a distinct species.

Of these three varieties, the specimens from the *Operculina*-Limestone at Ain Sciahat agree best with the var. *lorioli*; but they differ from it by having shorter, broad, and more distinctly closed petals.

Cl. subplacunarius Fuchs[4] is a Miocene species from Siwa, which offers some striking resemblances to *Cl. biarritzensis*; but *Cl. subplacunarius* has longer petals, and they are represented on Fuchs's figures as quite closed; the test, moreover, is flatter in proportion

---

[1] P. de Loriol, 'Eoc. Ech. Ægypt.' Palæontographica, vol. xxx, pt. 2 (1903) p. 12 & pl. i, figs. 18–19 *a*.

[2] P. Oppenheim, 'Die Priabonaschichten & ihre Fauna' Palæontographica, vol. xlvii (1900–1901) p. 92 & pl. xv, fig. 18.

[3] *Id.* 'Rev. Tert. Ech. Venet. &c.' Zeitschr. Deutsch. Geol. Gesellsch. vol. liv (1902) p. 190.

[4] 'Beitr. Kennt. Miocänfauna Ægyptens & der Libyschen Wüste' Palæontographica, vol. xxx, pt. 1 (1883) p. 47 [29] & pl. xvi [xi] figs. 1–3.

to its length, and has a more even slope from the apex to the front edge. *Cl. goirensis* D. & S.,[1] from the Miocene of Kach, is another similar species, as it is very closely allied to *Cl. subplacunarius*; but it differs therefrom by its wider petals.

FIBULARIA LUCIANI (de Loriol) 1880.

Echinocyamus luciani de Loriol, 1880, 'Monogr. Éch. Nummul. Égypte' Mém. Soc. Phys. Hist. Nat. Genève, vol. xxvii, pt. 1, p. 74 & pl. ii, figs. 8–15 *a*.
Echinocyamus luciani de Loriol, 1883, 'Eoc. Ech. Ægypt.' Palæontographica, vol. xxx, pt. 2 (1903) p. 11 & pl. i, figs. 13 *a*–13 *d*.
Thagastea luciani Fourtau, 1899, 'Rev. Éch. Foss. Égypte' Mém. Inst. Égypt. vol. iii, fasc. 8, p. 642.

Distribution.—Egypt: Middle Eocene, Mokattam and Wadi el Tih, near Cairo. Cyrenaica: Middle Eocene, in white marly limestone (at 1215 feet above sea-level), near the foot of the escarpment north of Cyrene.

Dimensions in millimetres:—

	Larger specimen.	*De Loriol's type.*
Length	5·5	3 to 11.
Breadth	4·5	66–73 per cent. of length.
Height	3·0	55–65 „ „

Affinities.—The collection includes two specimens (Cy 78) of a *Fibularia* from a bed of soft marly limestone cropping out northeast of our camp at Ain Sciahat, below the Roman road to Mersa Susa, and beneath the soft shelly limestone (Cy 77) on the face of the upper escarpment. As only two specimens were collected, it is not advisable to destroy one in order to verify the absence of the septa—the essential distinction between *Fibularia* and *Echinocyamus*: for the echinoids have the height and egg-shaped form characteristic of *Fibularia*. Agassiz indeed separated *Fibularia* from *Echinocyamus* by its subglobular form.

De Loriol described the species as subconical, and remarked its affinity to *Fibularia*. Fourtau in his 'Revision' has transferred the species to the genus *Thagastea* of Pomel; but, as he says that the only difference between *Thagastea* and *Fibularia* is that the former is more elongated and irregular in shape, the genus appears unnecessary. The smooth anterior peristomal depression, which Pomel used as the essential feature of *Thagastea*, is even less adequate as a generic character.

The nearest allied species is the *Echinocyamus rotundus* of Duncan & Sladen,[2] from the Upper Eocene or Khirthar Series of Sind. That species is much higher than is usual in *Echinocyamus*; its length is 9 millimetres, its breadth 8·75 mm. and height 5 mm.; but, if *E. rotundus* be a *Fibularia*, it can be distinguished from the Cyrenaican species by the upper surface rising to a sharp summit

---

[1] P. M. Duncan & W. P. Sladen, 'Foss. Ech. of Kachh & Kattywar' Pal. Ind. (Geol. Surv. India) ser. xiv, vol. i, pt. 4 (1883) p. 59 & pl. xii, figs. 14, 16.

[2] P. M. Duncan & W. P. Sladen, 'Foss. Ech. W. Sind' Pal. Ind. (Geol. Surv. India) ser. xiv, vol. i, pt. 3, fasc. 3 (1884) p. 135 & pl. xxv, figs. 33–37.

at the anterior end of the test. The same character occurs in the Langhian *Fibularia pseudopusilla* Cott., of Sardinia.[1]

Among species from higher horizons, it is natural first to compare the Cyrenaican specimens with *E. studeri* (Sism.), as that species was referred by Sismonda to *Fibularia*; but, as Agassiz & Desor remarked, when referring it to *Echinocyamus* in the 'Catalogue Raisonné,'[2] it is very elongated and 'très plate.' The Maltese specimens figured in 1891[3] as *E. studeri* are far more depressed in form. They have since been separated by M. J. Lambert as *F. melitensis*,[4] owing to their less oval shape and less marginal periproct than the specimens figured by G. Capeder as *E. studeri*[5]; but, according to the latter, the specimens which he refers to *E. studeri* have a ratio of height to length of 1 to 1·9 mm. (*op. cit.* p. 508), which does not correspond with the statement in Agassiz's diagnosis that the form is 'très plate.' According to M. Lambert, *E. studeri* is even flatter than a species in which the ratio of height to length is as 1·5 to 4·25.[6] Signor Capeder has described twenty-five species, of which nineteen are new and come from one locality in Sardinia. On those lines the Maltese specimens should be distributed among several species.

Gauthier[7] has described *Echinocyamus thuilei* from the Helvetian of Gebel Geneffe near Suez; this echinoid is 12 millimetres long, 9 mm. wide, and 3·5 mm. high, so that it is much flatter than the specimens from Cyrene.

The flat upper surface of the Cyrenaican specimens resembles that of *Fibularia calarensis* Lambert (*loc. cit.*), from the Helvetian of Cagliari; but that species is nearly thrice as long as high (1·5 to 4·25 mm.).

SCUTELLA TENERA Laube, 1868.

Scutella tenera Laube, 1868, 'Beitr. zur. Kenntniss d. Ech. Vic. Tert.' Denkschr. K. Akad. Wiss. Wien, vol. xxix, pt. 2, p. 18 & pl. ii, fig. 7.

Scutella tenera Dames, 1877, 'Ech. Vic. & Ver. Tert.' Palæontographica, vol. xxv, p. 22.

Scutella tenera Oppenheim, 1902, 'Revis. Tert. Ech. Venet. &c.' Zeitschr. Deutsch. Geol. Gesellsch. vol. liv, p. 192.

Scutella cavipetala Laube, 1868, *op. cit.* p. 17 & pl. ii, fig. 6.

---

[1] See, for example, J. Lambert, 'Éch. Foss. Terr. Mioc. Sardaigne' Abhandl. Schweiz. Paläont. Gesellsch. vol. xxxiv (1907) pl. iii, fig. 19.

[2] L. Agassiz & E. Desor, 'Cat. Rais.' Ann. Sci. Nat. [Zool.] ser. 3, vol. vii (1847) p. 142.

[3] J. W. Gregory, 'The Maltese Fossil Echinoidea' Trans. R. Soc. Edin. vol. xxxvi, pt. iii, no. 22 (1891) pl. i, figs. 8–10 *c*.

[4] J. Lambert, 'Éch. Foss. Terr. Mioc. Sardaigne' Abhandl. Schweiz. Paläont. Gesellsch. vol. xxxv (1908) p. 127.

[5] 'Fibularidi del Miocene medio di S. Gavino a Mare (Portotorres) Sardegna' Boll. Soc. Geol. Ital. vol. xxv (1906) pl. x, figs. 5 *a*–5 *d*.

[6] J. Lambert, 'Éch. Foss. Terr. Mioc. Sardaigne' Abhandl. Schweiz. Paläont. Gesellsch. vol. xxxiv (1907) p. 40 & pl. ii, figs. 27–31 (*Fibularia calarensis*).

[7] In Fourtau, 'Rev. Ech. Foss. Égypte' Mém. Inst. Égypt. vol. iii, fasc. 8 (1899) p. 696 & pl. ii, figs. 11–13.

Dimensions in millimetres.	Cy 60.	*S. striatula* Cotteau's fig.	*S. tenera* Laube.	*S. cavipetala* Laube.
Length	50	50	56	67
Breadth	57	52	58	68
Antero-lateral petal :—				
Length	11	13	11	16
Breadth	6	5	5·5	8
Distance from proximal end of that petal to margin of test	22	23·5	25	32

Distribution.—Lower Oligocene: Tongrian of Northern Italy; in the tuffs at Laverda, Gnata di Salcedo, and Sangonini di Lugo, In Cyrenaica, in the Slonta Limestones at Labruk (Cy 60); Bir Hu, 5 miles south of Cyrene (Cy 297); and ? north of Ain Sciahat (Cy 73).

Affinities.—Dames has pointed out that the depression of the petals in *S. cavipetala* was due to pressure, and that the species must be merged in *S. tenera.*

This species is represented by three specimens; but the third, found at Ain Sciahat, is poorly preserved, and its identification is somewhat doubtful.

The species resembles in outline *Scutella ammonis* Fuchs, from the Miocene of Siwa, which has, however, longer petals. In *S. tenera* the ratio between the length of the anterior petal and the distance from its inner end to the edge of the test is as 11 : 27, whereas in *S. ammonis* the ratio is as 16 : 29. The petals of *S. tenera* are also broader and more ovate than in *S. ammonis.*

Scutella tenera is unquestionably closely allied to *S. striatula* Marc. de Serr., the well known Lower Oligocene species, the range of which has been extended down to the Middle Eocene by Cotteau[1] in the Gironde, and to the Priabonian by Commander Flick in Tunisia.[2] Laube's figure of *S. tenera* has a less sinuous outline, but that of his *S. cavipetala* agrees with that of *S. striatula*; and *S. cavipetala* having been merged in *S. tenera*, the regular outline is not available as a distinction. Laube remarked, as a character separating *S. tenera* from *S. striatula*, that in the former the petals are wider in proportion to the length; and according to that feature, as shown by the above table of dimensions, the specimens from Cyrenaica agree with *S. tenera.*

Scutella sp.

A large *Scutella* with long petals occurs in the limestone on the plains east of Benghazi; but the fragments collected are undeterminable, and I was unable to return to the locality to get

---

[1] 'Éch. Éoc., Pal. Franç.: Terr. Tert.' vol. ii (1891) p. 242.

[2] 'Priabonien en Tunisie' C. R. Acad. Sci. Paris, vol. cxxx, p. 149.

complete specimens. From sketches made in the field, the species resembles *S. lusitanica* de Lor.[1] from the Middle Miocene (beds III–V *a*, of Cotter's stratigraphical table) of Portugal.[2]

Scutella hunteri[3] Fourtau, from the Helvetian of Marmarica, is smaller, and has shorter petals. M. Lambert has described several new species of the Mediterranean Miocene *Scutellæ* (*S. almerai*, *S. sardica*, and *S. tarraconensis*), but they do not correspond with my measurements of the Cyrenaican species.

The *Scutella* occurred with fragments of a large *Clypeaster*, which supports the probable Miocene age of this limestone.

AMPHIOPE DUFFI, sp. nov.[4] (Pl. XLVII, figs. 2 & 3.)

Test thin, breadth approximately equal to the length. The greatest breadth is behind the apical disc. The test contracts slightly towards the anterior end. Margin slightly sinuous. The front half of the test is thicker than the posterior half. The petals are oval; the length is about equal to half the distance from the centre of the test to the margin. Apical disc central. Lunules wide and suboval, but bluntly pointed at the ends: the lunules occur near the edge of the test.

Dimensions in millimetres:—

	Cy 264.	Cy 66.	*A. arcuata.*
Length	...	41	80
Breadth	...	41	80
Height	2	2·5	8
Antero-lateral petal: length	8	9	
Do. do. breadth	4	4·5	

Distribution.—In a nummulitic limestone: Sidi Rof Diasiasia, south-east of Cyrene (Cy 66). Near the camp at Ain Sciahat, Cyrene (Cy 264). Both specimens occur in nummulitic limestone, and Mr. R. B. Newton remarks that the specimen from Ain Sciahat includes foraminifera resembling *Nummulites complanata*.

Affinities.—This species is interesting, owing to the early occurrence of the genus. Both specimens are poorly preserved, as well as some fragments which appear to belong to this species; but the lunules are shown so distinctly that there can be no doubt of the generic determination; and the genus is most abundantly represented in the Miocene.

The nearest ally of this species is *A. arcuata* (Fuchs) from the Miocene of Siwa. The two species, however, differ, as in *A. duffi* the test tapers less anteriorly, the petals are oval rather than clavate, the lunules are rather more pointed, and the size is much smaller.

---

[1] 'Éch. Tert. Portugal' Dir. Trav. Géol. Portugal, 1896, p. 12 & pl. ii, figs. 1–3 *c*.

[2] *Ibid.* pl. v, p. 50.

[3] D. E. Pachundaki, 'Contrib. Étude Géol. de Marsa Matrouh (Marmarique)' Rev. Internat. Égypte, vol. iv (1907) p. 24 & pl. ii, fig. 3.

[4] Named after my colleague in the expedition, Mr. M. B. Duff, to whom is due the topographical map.

I originally regarded these specimens as young forms of *A. arcuata*. Dr. Pervinquière[1] has reported an *Amphiope* with incompletely closed lunules, from the Priabonian of Tunis.

AMPHIOPE sp.

The collection also includes a fragment (Cy 82) of an *Amphiope* with long lunules, from the Aquitanian *Pecten* Bed at Ain Sciahat.

ECHINOLAMPAS.

The collection includes a series of specimens of *Echinolampas* of which the specific determination is difficult, as most of them have been damaged by sand erosion.

The genus *Echinolampas* includes a large number of species distinguished mainly by the shape of the test, a character of uncertain value; and, although the approximate stratigraphical horizon may be safely inferred from a number of specimens, the specific identification of single specimens is usually difficult in this genus.

The specimens of *Echinolampas* were mostly found in Central Cyrenaica, and the chief *Echinolampas* Bed is a well defined horizon. The matrix of most of the specimens contains foraminifera, which Mr. Newton has determined as nummulites; and Mr. Chapman has identified specimens from this bed as *Nummulites gizehensis*, var. *lyelli*. The *Echinolampas* was never found associated with the Middle Eocene form of *N. gizehensis*, but with the later smaller varieties.

It is natural at first to compare the *Echinolampas* with those from the Egyptian Eocene, which contains many easily recognizable species such as *E. osiris*, *E. africanus*, *E. crameri*, *E. globulus*, but none of them were found in Cyrenaica. Nine species of *Echinolampas* are described by Dr. Oppenheim from the Priabonian beds of Northern Italy; but the most easily determined of those species, such as the massive *E. montevialensis* Schaur., or *E. beaumonti* Ag., are not represented. The most abundant of the Cyrenaican Echinolampads is a species with a subpentagonal outline, a concave base, and having the summit of the test behind the apical disc. Different varieties are more rounded and oval in plan, or are higher, or have the posterior half of the test more expanded.

The general practice in regard to this genus is to treat these variations as specific; but M. Lambert, who has had especial experience of the genus, has kindly examined six of the specimens representing the different forms. He regards them all as individual variations of a single species, which includes also the Upper Eocene Tunisian echinoids originally referred to *E. perrieri*. He says in a letter:—

'En résumé, sans trancher la question de l'identité de l'*E. perrieri* de la

---

[1] 'Étude Géologique de la Tunisie Centrale' Carte Géol. Tunisie, 1903, p. 200.

Tunisie avec l'*E. perrieri* de l'Égypte, je crois qu'il existe dans l'Afrique du Nord, dans la Cyrénaïque et la Tunisie, un *Echinolampas* de forme assez variable, à pétales plus ou moins développés, qui constitue une espèce actuellement réunie par les auteurs à l'*E. perrieri* de Loriol des environs de Thèbes.

'Je n'hésite donc pas à déterminer ces *Echinolampas* Nos. 229, 279, etc., comme *Echinolampas perrieri* Cotteau, mais je n'ai pas de matériaux suffisants pour affirmer l'identité de cette forme avec l'*E. perrieri* de Loriol.'

M. Gauthier has established the name *E. chericherensis* for these Tunisian echinoids, and that name may be provisionally accepted. The inclusion of such wide variations in one species will render necessary the abandonment of several accepted species, and the name *chericherensis* will doubtless have to be abandoned in favour of some earlier name; but it may be conveniently used until this group of species has been revised.

ECHINOLAMPAS CHERICHERENSIS Gauthier, 1899. (Pl. XLVIII, figs. 1 *a*, 1 *b*, & 2; Pl. XLIX, figs. 1–3.)

Echinolampas chericherensis Gauthier in Fourtau, 1899, 'Rev. Éch. Foss. Égypte' Mém. Inst. Égypt. vol. iii, fasc. 8, p. 732.
Echinolampas chericherensis Pervinquière, 1903, 'Géol. Tunisie Centrale' Carte Géol. Tunisie, pp. 198, 200, 201, 202, 204.
Echinolampas perrieri Cotteau, 1890, 'Éch. Éoc., Pal. Franç.: Terr. Tert.' vol. ii, p. 126 & pls. ccxli, ccxlii, figs. 1–2.
Echinolampas perrieri Gauthier in Fourtau, 1899, *op. cit.* p. 659.
Echinolampas perrieri Flick, 1900, 'Priabonien en Tunisie' C. R. Acad. Sci. Paris, vol. cxxx, p. 149.
Non *Echinolampas perrieri* de Loriol, 1880, 'Monogr. Éch. Nummul. Égypt.' Mém. Soc. Phys. Hist. Nat. Genève, vol. xxvii, pt. i, p. 95 & pl. v, figs. 2–2 *b*.
Non *Echinolampas perrieri* de Loriol, 1883, 'Eoc. Ech. Ægypt.' Palæontographica, vol. xxx, pt. 2, p. 25 & pl. vii, figs. 2–3 *a*.
Echinolampas zignoi Oppenheim, 1900, 'Priabonaschichten' Palæontographica, vol. xlvii, p. 103 & pl. ix, figs. 3–3 *b*.
Echinolampas hydrocephalus Oppenheim, 1900, *ibid.* p. 103 & pl. xvii, figs. 5–5 *b*.
Echinolampas blainvillei Oppenheim, 1900, *ibid.* p. 102 & pl. ix, figs. 1–1 *b*.
Non *Echinolampas blainvillei* Agassiz, 1847, 'Cat. Rais.' Ann. Sci. Nat. [Zool.] ser. 3, vol. vii, p. 164.
Non *Echinolampas blainvillei* Tournouer, 1869, 'Rec. Éch. de l'Étage du Calcaire à Astéries du S.O. de la France' Actes Soc. Linn. Bordeaux, vol. xxvii, pp. 286–90 & pl. xvi, figs. 1–3.

The echinoids referred, in deference to M. Lambert's opinion, to one species include five main variations.

The commonest form (var. *a*) most resembles Dr. Oppenheim's *blainvillei*, with a pentagonal form and a well-rounded upper surface.

Var. *b* is a more flattened variety, which is also subpentagonal; it has affinities with *E. falloti* Cott.,[1] but is more depressed.

Var. *c* approaches most nearly to the Tunisian forms figured by Cotteau, which may be regarded as the type of *E. chericherensis*.

Var. *d* is the same as Dr. Oppenheim's *E. hydrocephalus*.

Var. *e* is unusually wide behind, and approximates to the Tongrian *E. posterolatus* Greg.

---

[1] G. Cotteau, 'Éch. Éoc., Pal. Franç.: Terr. Tert.' vol. ii (1894) p. 737 & pl. ccclxxix, figs. 1–3.

Dimensions in millimetres.—The following list shows the range of variation in shape and size:—

Var. *a*.

	Length.	*Breadth.*	*Height.*
Cy 60. Labruk	56	52	25
"	58	54	24
131. East of Wadi Gharib	49	45	23
229*a*. East of Slonta	51·5	50·5	22·5
229*c*. Do. do.	?	50?	22
284. South of Wadi Firyah	53	50·5	23
295. Slonta	60	55	25
267. Wadi Firyah	51	45	?24
279. Do. do.	?59	56	25
291. North of Roman Camp, north-west of Slonta	?	54	27

Var. *b*.

	Length.	*Breadth.*	*Height.*
144.	59	57	21·5
279.	56	51	?23
60.	57	52	22
217.	55	51	21
E. falloti Cotteau	55	47	27
	51	45	27

Var. *c*.

	Length.	*Breadth.*	*Height.*
82.	?57	50	28
74.	60	?50	25
264.	55	51	28·5
E. perrieri de Loriol	52/56	82 %	42/45 %
Do. Cotteau	62	55=89 %	28=45 %
E. zignoi Opp.	49	84 %	43 %

Var. *d*.

	Length.	*Breadth.*	*Height.*
151.	59	57	30·5
221.	47	46	23.
229.	56	51?	29
229*b*.	55?	52	26·5
295*a*.	55?	49	28
Dr. Oppenheim's *hydrocephalus*	53	45	27 L:h as 2:1
	77	64	34 L:h as 7:3

Distribution.—Upper Eocene: characteristically Priabonian in Tunisia, in the Wadi Cherichera, G. Gebil (Djebil), Gebel Nasser, Allah, Gebel Batène and Wadi Bogal, etc.; in Northern Italy at Lonigo, Possagno, etc.

? Bartonian: beds with *Nummulites fichteli*, east of Siwa.

Cyrenaica: in the Slonta Limestone.

Var. *a* at Labruk, east of Wadi Gharib (the westernmost locality at which *Echinolampas* was found); Messa; Wadi Firyah; and between Wadi Firyah and the shrine of Sidi Mahomet Mahridi, east of Slonta; north of the Roman Camp, north-west of Slonta.

Var. *b* at Wadi Jeraib, east of Gasr el Migdum (Cy 144); Labruk (Cy 60); Wadi Firyah (Cy 279); Bir Hu, 5 miles south of Cyrene; 2 miles south-east of Messa (Cy 217).

Var. *c*: Ain Sciahat.

Var. *d*: Slonta (Cy 295 *a* and 151); east of Slonta (229); with *Fimbria lamellosa* and *Scutella* sp., at some old cisterns, east of Slonta (294 *a*).

Var. *e*: plateau near Messa; and south of Wadi Firyah, north-east of Slonta.

ECHINOLAMPAS DISCUS Desor, 1858.

Echinolampas discus Desor, 1858, 'Syn. Éch. Foss.' p. 307.
Echinolampas discus Dames, 1877, 'Ech. Vic. & Ver. Tert.' Palæontographica, vol. xxv, p. 43 & pl. iii, figs. 1 *a*–1 *c*.
Echinolampas discus Oppenheim, 1902, 'Rev. Tert. Ech. Venet. &c.' Zeitschr. Deutsch. Geol. Gesellsch. vol. liv, p. 216.

Distribution.—Italy: Schioschichten, Aquitanian. Castello di Schio, Rocca di Garda, etc. Cyrenaica: in grey *Operculina*-Limestone, 150 feet above the Fountain of Apollo, Ain Sciahat, Cyrene.

Dimensions in millimetres:—

	Cyrene No. 9.	Dames's figured specimen.	*E. amplus* Fuchs.
Length	about 90	73	120
Breadth	86	68	110
Height	26	30	37
	(a little flattened by crushing).		

Affinities.—This species has been recorded by Cotteau from the Eocene of Alicante in Spain; but Dr. Oppenheim throws doubt on the identification, and it requires confirmation. Dames regards Laube's *Echinolampas conicus*[1] as a synonym, although Laube's figure represents the apical disc as behind the centre, instead of well to the front; the antero-lateral ambulacra of *E. conicus* are also represented as straighter.

The species is closely allied to *E. amplus*, Fuchs[2] from the Miocene of Siwa; but *E. amplus* is flatter, and has a more central apex and broader poriferous zones in the ambulacra.

HYPSOCLYPEUS HEMISPHERICUS (Gregory), 1891.

Heteroclypeus hemisphericus Gregory, 1891, 'Maltese Foss. Ech.' Trans. Roy. Soc. Edin. vol. xxxvi, pt. iii, No. 22, p. 598 & pl. i, figs. 11 *a*–11 *c*.

An echinoid (Cy 48) from Birlibah raises the question of the relations of the genera *Heteroclypeus* and *Conoclypeus* to the Echinolampads. This specimen has most of the base broken away; but the upper surface is well-preserved, and the chief characters of the peristome can be recognized. It belongs to the Maltese species founded in 1891, under the name of *Heteroclypeus hemisphericus*,

---

[1] G. C. Laube, 'Beitr. Kennt. Ech. Vic. Tert.' Denkschr. K. Akad. Wissensch. Wien, vol. xxix, pt. ii (1868) p. 25 & pl. v, figs. 2 *a*-2 *b*.

[2] T. Fuchs, 'Beitr. Kennt. Mioc. Ægypt.' Palæontographica, vol. xxx, pt. 1 (1883) pp. 45, 63 & pl. xiv (ix), figs. 5–8.

of which specimens had been previously identified by Wright[1] as *Conoclypeus plagiosomus* Ag. That species was founded by Agassiz[2] in the 'Catalogue Raisonné' on specimens from the Molasse of Southern France, and he then described it as

> 'renflée, à bords tranchants, remarquable par ses zones porifères très étroites.'

Figures showing these characters have been given, as, for example, by Laube[3]; and they also show that the peristome has very projecting bourrelets. In the Maltese species the peristome is very different from that of *C. plagiosomus*, as may be seen by comparison of Laube's figure with that of *H. hemisphericus*.[4] The resemblances, however, between the two species and the inversion of the peristome led me to assume that the Maltese echinoid had small jaws, though no fragments of them had been found. I accordingly referred the species to Cotteau's genus *Heteroclypeus*. Dr. Stefanini[5] has called attention to the probably complete absence of jaws, and has removed the species from the Conoclypeidæ to the Cassidulidæ, a conclusion which seems to me correct; but Stefanini has gone further than I can follow him in placing the species in *Echinolampas*. The genus *Echinolampas* includes a large number of species, and it seems to me undesirable to include this very distinct type in it.

Echinolampas was founded by J. E. Gray[6] in 1825, but he did not then distinctly select any one species as a type. Of the species that he mentioned, *E. oviformis* was the best known and has been practically adopted as the type. The *Echinolampas* from Malta and Birlibah does not agree with this form of Echinolampad. It is much nearer to the genus *Palæolampas* of Bell, with which it agrees in its large size, its circular or subcircular shape, the extension of the petals to the margin of the test, and the subequal length of the poriferous areas in each ambulacrum. The Echinoid also agrees with *Hypsoclypeus* of Dr. A. Pomel,[7] in which Agassiz's species *plagiosomus* was expressly included. The difference between *Palæolampas* and *Hypsoclypeus* is perhaps not very important, but it is accepted and perhaps overrated by M. Lambert: it depends mainly on the structure of the peristome. *Palæolampas*, according to Prof. J. F. Bell's diagnosis, has the bourrelets feebly developed,[8]

---

[1] T. Wright, 'Foss. Echinidea of Malta' Q. J. G. S. vol. xx (1864) p. 483.

[2] L. Agassiz & Desor, 'Cat. Rais.' Ann. Sci. Nat. [Zool.] ser. 3, vol. vii (1847) p. 168.

[3] 'Ech. Œsterr.-Ungar. Ob. Tert.' Abhandl. K.-K. Geol. Reichsanst. vol. v, pt. 3 (1871) p. 67 & pl. xix, fig. 3.

[4] J. W. Gregory, 'Maltese Fossil Ech.' Trans. Roy. Soc. Edin. vol. xxxvi, pt. iii, No. 22 (1891) pl. i, fig. 11 *b*.

[5] 'Conoclipeidi & Cassidulidi Conoclipeiformi' Boll. Soc. Geol. Ital. vol. xxvi (1907) p. 366; and 'Ech. Mioc. Malta nel Museo di Firenze' *ibid.* vol. xxvii (1908) p. 456.

[6] 'An Attempt to Divide the Echinida, or Sea-Eggs, into Natural Families,' Ann. Phil. vol. xxvi (1825) p. 429.

[7] 'Classification Méthodique & Genera des Échinides Vivants & Fossiles' Algiers, 1883, p. 63.

[8] 'On *Palæolampas*' Proc. Zool. Soc. 1880, p. 48.

whereas in *Hypsoclypeus* the bourrelets are much more prominent.[1] In this respect, the species founded as *Heteroclypeus hemisphericus* agrees with *Hypsoclypeus.* The inclusion of this species in *Echinolampas* seems impossible, without merging in that genus several genera that are now accepted.[2] The excellent figures published by Dr. Stefanini of Airaghi's species, *Echinolampas pignatarii,* show its identity, as Stefanini has pointed out, with the *H. hemisphericus* from Malta; and as there is an old-established species of *Echinolampas* named *hemisphericus,* he merged the Maltese species in *E. pignatarii* Air. The exclusion of *H. hemisphericus* from *Echinolampas,* however, allows it to retain its older specific name, which dates from 1891.

M. Lambert[3] has suggested that *Hypsoclypeus hemisphericus* is the young of Pomel's *H. doma.*[4] That view seems to me improbable, as the type of the Maltese species is both longer and wider than any of the four specimens of *H. doma* of which the dimensions are stated by Pomel. *H. hemisphericus* has the height less than half the length (64 mm. to 155 mm.); whereas, of the specimens of *H. doma* of which Pomel gave dimensions, the height is half the length in the figured type, more than half the length in another, and slightly less in a third; and yet the flattest specimen is still higher proportionately than *H. hemisphericus.* In *H. doma* the apex is before the centre, and in *H. hemisphericus* behind the centre. Moreover, *H. doma* is of Cartennian (that is, of Burdigalian or Langhian) age, and *H. hemisphericus* is from the higher series, the Helvetian.

HEMIASTER SCILLÆ Wright, 1855.

J. W. Gregory, 'Maltese Foss. Ech.' Trans. Roy. Soc. Edin. vol. xxxvi (1891) p. 611.
Opissaster scillæ Stefanini, 'Ech. Mioc. di Malta nel Museo di Firenze' Boll. Soc. Geol. Ital. vol. xxvii (1908) p. 470 & pl. xvii, fig. 7.

Distribution.—Malta: Seam No. 4 of the *Globigerina* Limestone (Aquitanian) at Fommer Reh. In Cyrenaica: 100 feet above the camp at Ain Sciahat.

The upper surface of the one specimen found is so damaged that the fasciole is not visible, but the echinoid has the distinctive form of this species. Its length is 45 millimetres, width 43 mm., and height 35·5 mm.

---

[1] M. Lambert, however, instead of taking Bell's one species as the type of the genus, accepts *E. hoffmanni* Desor as the type, and accordingly describes *Palæolampas* as having the floscelle much better developed than in *Echinolampas, Hypsoclypeus,* etc.: 'Étude sur les Échinides de la Molasse de Vence' Ann. Soc. Lettres, Sci. & Arts des Alpes-Maritimes, vol. xx (1906) p. 33.

[2] M. Lambert (*ibid.* p. 33) founded a new genus *Scutolampas* on *E. plagiosomus,* which he has abandoned as a synonym of *Hypsoclypeus.*

[3] 'Descr. Ech. foss. Terr. Mioc. Sardaigne' Abhandl. Schweiz. Pal. Gesellsch. vol. xxxiv (1907) p. 54. This question is discussed by Dr. Stefanini, who maintains the two species, in Boll. Soc. Geol. Ital. vol. xxvii (1908) pp. 459–60.

[4] A. Pomel, 'Paléont. Algérie—Zooph. Fasc. 2, Échinodermes' livr. ii (1887) p. 163, pl. B ii, figs. 1–3. The text refers to figures of the species in pls. B ii bis & B iii, but these plates are not present in the Natural History Museum copy, and were apparently never published.

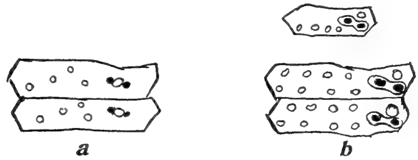
SCHIZASTER EDERI,[1] sp. nov. (Pl. XLVII, figs. 4 *a*–4 *c*.)

Diagnosis.—Test: cordate; the breadth is equal to or slightly greater than the length. The greatest breadth is about half-way along the length of the test. The test is high, and raised behind to a prominent keel. The summit is very excentric posteriorly at only a fifth of the length from the posterior end. The apical disc is a little behind the centre. There is a long gradual slope forward from the summit nearly to the anterior edge, where the ambitus is steep and well rounded.

Petals: deeply sunk.

The anterior ambulacral furrow is long, and has long steep parallel sides, as also small numerous pores. The pores in each pair are bigeminate, and on the apical side of the plate is a conspicuous granule immediately above the pore-pairs (fig. *b*). The plates in the anterior ambulacral furrows have numerous crowded granules arranged in two rows along each plate, with about four granules in each row.

The granulation of the anterior ambulacral plates in a *&* b.



a = *Sch. rimosus*, after Cotteau, 'Pal. Franç.: Éch. Éoc.' pl. c, fig. 5.
b = *Schizaster ederi*, sp. nov.

Antero-lateral petals long and but slightly sinuous, with thirty pairs of pores on each side. Postero-lateral petals short and deep, and curved backwards beside the keel: they have twenty-two pairs of pores on each side, of which the seven pairs nearest the apical disc are much smaller than the others; the difference in size is abrupt.

Periproct large and oval, pointed above and below, raised high on the posterior wall, and beneath a slightly overhanging projection from the keel. Peristome near the anterior edge.

Dimensions:—

			Sch. desori.	
	Sch. ederi.	*Sch. rimosus* (Cotteau).	Wright's text.	Wright's fig.
	mm.	mm.	inches.	mm.
Length	48	59	2·8	54
Breadth	49	55	2·7	50
Height	32½	33	1·8	(35?)
Length of antero-lateral petal	16	21	1·3	16
Length of postero-lateral petal	10	10	0·75	11

---

[1] Named after Dr. M. D. Eder, the doctor of the Expedition.

Distribution.—In a yellow-weathering, marly limestone, near the Fountain of Apollo at Cyrene; and at Gasr el Harib, near Derna. Age, Aquitanian.

Cy 100. Type-specimen. 150 feet below camp at Ain Sciahat.
Cy 264. Broken specimen. Plateau above camp at Ain Sciahat.
Cy 102. Broken and crushed specimen. Plateau above camp at Ain Sciahat.
Cy 126. Young specimen, 37·5 mm. long and 38 mm. wide (slightly crushed). Camp at Ain Sciahat.
Cy 24. Flat crushed specimen, in soft yellow limestone. Plateau at Gasr el Harib, east of Derna.

Affinities.—In the field—trusting only to memory of the species—I identified this echinoid as *Sch. desori*, the Aquitanian-Langhian species from Malta. On studying the collection after my return, I at once compared it with the Priabonian *Sch. rimosus* Ag. The dimensions, as shown by the table quoted above, seemed to me to indicate that the affinities of the species are nearer to *Sch. desori*. M. Lambert, however, who has kindly examined the best specimen, regards it as nearer *Sch. rimosus*, though distinct from that species, than it is to *Sch. desori*, from which he says it is 'bien différent.' It certainly is nearer to *rimosus* in some features of its shape. From both these species the Cyrenaican *Schizaster* differs by its greater breadth, which is slightly more than the length.

The granulation of the plates in the anterior ambulacral furrow of *Sch. rimosus*, according to Cotteau's figure ('Éch. Éoc., Pal. Franç.: Terr. Tert.' pl. c, fig. 5), consists of sparse irregularly scattered granules, whereas in this species the granules are crowded and arranged in irregular longitudinal rows. The antero-lateral petals appear to me shorter, straighter, and broader than in *Sch. rimosus*, though the numbers of the pores in the paired petals of *rimosus* (31), *desori* (30), and *ederi* (30) are practically the same.

M. Lambert remarks about the species that

> '*S. rimosus* Desor, du Tongrien de Biarritz, est voisin, mais non identique. Le sillon entame davantage le bord chez le *Schizaster* de la Cyrénaïque; son péristome est plus excentrique, son fasciole est plus coudé. Ce *Schizaster* constitue probablement une espèce nouvelle.'

Schizaster ederi may be regarded as a form tending to link *Sch. desori* and *Sch. rimosus*.

SARSELLA LAMBERTI,[1] sp. nov. (Pl. XLVIII, figs. 3 *a* & 3 *b*.)

Diagnosis.—Test small, heart-shaped, with a broad shallow anterior notch. The breadth of the test is equal to the length. The greatest width is at about two-fifths of the length from the anterior end. The posterior end is truncate, and the straight side there helps to impart to the test a somewhat hexagonal outline.

The test appears flat when seen from the side; the sides slope gently down from the low median ridge. The anterior margin is

---

[1] Named after M. Jules Lambert, President of the Civil Tribunal, Troyes, the distinguished authority on the Kainozoic Echinoids of the Mediterranean Basin.

steep and the front part of the anterior sulcus is almost vertical for nearly the full thickness of the test.

The apical disc is opposite the widest part of the test, and the area within the internal fasciole extends forwards as a flat platform, from which the antero-lateral petals diverge almost at right angles. Atrophy of the inner pores of the antero-lateral petals by the internal fasciole has reduced them to ten pairs in the anterior zone, while the posterior zone has thirteen pairs. The posterior zone is very sinuous, and the middle pore-pairs are very wide.

Large tubercles rising from the depressed scrobicular pits occur in the anterior corner of the test; there are eight before and twelve behind each antero-lateral petal.

Periproct well raised on the posterior wall, which appears to slope slightly downwards posteriorly, so that the periproct would not be seen from below.

Plastron broad, slightly raised above the lateral areas, which are covered with crowded coarse tubercles. The plastron expands in width gradually backwards. Owing to its elevation the plastron has been worn, and leaves only faint traces of the small tubercles with which it was provided.

Dimensions.—Length = 42 mm.; breadth = 42 mm.; height = 16 mm.; length of functional part of antero-lateral petal = 12 mm.; length of postero-lateral petal = 16 mm.

Distribution.—In yellow argillaceous limestone with *Operculina libyca*: Cyrene Limestones (Aquitanian). Near Ain Sciahat, Cyrene.

Affinities.—The genera *Lovenia* and *Sarsella* are separated by the presence of ampullæ in the former. The side of this specimen has been cut away in order to determine their presence, but they appear to be absent. There are some reasons for doubting the value of this character; but, if it be accepted, this species is a *Sarsella*.

The species with which, however, it offers closest resemblance is the *S. sulcata* of Haime, which according to M. Lambert is a *Lovenia*. *S. lamberti* and *S. sulcata* differ, however, in several well-marked characters. Thus the antero-lateral ambulacra project forward in *S. sulcata* more than in *S. lamberti*, though they agree in the number of pores and in the proportion atrophied by the expansion of the internal fasciolar area. The number of big depressed tubercles behind the antero-lateral petals is larger in *S. sulcata*, there being twenty-two instead of thirteen. *S. sulcata*, according to Cotteau's figure[1] (pl. xxii, fig. 2), has a rounded posterior end, but the specimen figured on his pl. xxiii, fig. 1, has a truncate posterior end like that of *S. lamberti*. *S. sulcata* is therefore a variable species. The excellent series of figures of *Breynia carinata* Arch. & H. given by Duncan & Sladen[2] show how variable are the most conspicuous specific characters in the genera *Lovenia*, *Sarsella*, and *Breynia*.

---

[1] G. Cotteau, 'Éch. Éoc., Pal. Franç.: Terr. Tert.' vol. i (1885–89).

[2] 'Ech. Western Sind' Pal. Ind. (Geol. Surv. India) ser. xiv, vol. i, pt. 3 (1885) pp. 343–54, pl. liv, figs. 1–9, & pl. lv, figs. 1–8.

M. Lambert has kindly examined this specimen, so as to compare it with *Lovenia sulcata* and his own *L. lorioli* Lb., and he regards it as distinct from them and as a new species. He says :—

> 'Elle se distingue de *S. sulcata* Haime (*Breynia*) par son sillon qui ne remonte pas jusqu'à l'apex et est remplacé en dessus par le petit bouclier plat circonscrit par le fasciole intrapétale. *S. lorioli* Lb., comme *S. mauritanica* Pomel plus étroit en arrière, ont leur face postérieure rentrante, tandis que cette face est oblique chez l'espèce de la Cyrénaïque. Le *S. mauritanica* Gauthier paraît être toute autre chose. *S. anteroalta* Gregory, pourvu d'ampoules internes et à plastron lisse, est un *Lovenia.* Il en serait de même de *Sarsella duncani* Gregory, d'après les figures de Wright; ce dernier est moins large en arrière, ses pores sont moins longuement atrophiés, le méplat entourné par le fasciole interne est chez lui moins saillant que chez l'espèce de la Cyrénaïque, qui me paraît constituer réellement une espèce nouvelle. *Eupatagus tuberculosus* Fraas, plus grand, aurait, d'après Gauthier, deux des branches de ses pétales pairs qui remonteraient jusqu'à l'apex sans s'atrophier ; il manquerait donc de fasciole interne.'

EUSPATANGUS sp.

A spatangoid from the *Operculina* Limestone at Ain Sciahat is too deformed and sand-worn for determination. The restricted distribution of the large tubercles indicates a peripetalous fasciole, and thus the genus is either *Breynia* or *Euspatangus.* M. Lambert has kindly examined the specimen, and suggests its comparison with *Euspatangus cossoni* Gauth., from the Upper Limestone with Nummulites, in the Gebel Cherichera in Tunisia. The subanal area is worn, but the echinoid probably had a subanal fasciole and is therefore a *Euspatangus* ; the species, however, is smaller, the anterior sulcus steeper, the anterior height greater, and the front steeper than in V. Gauthier's[1] type of *E. cossoni.*

The Affinities of the Echinoid Faunas.

The Echinoids belong to four horizons. The uppermost fauna is represented by some *Clypeaster* fragments and the *Hypsoclypeus* at Birlibah, and by the Scutellas and Clypeasters seen in the limestones on the coastal plain between the foot of the Tokra Scarp and Benghazi. The age is Miocene and probably Helvetian.

The second fauna includes *Echinolampas discus*, *Hemiaster scillæ*, *Schizaster ederi*, *Sarsella lamberti*, *Euspatangus* sp., and *Clypeaster biarritzensis* var. *trotteri.* The typical form of the last species is Upper Eocene. According to M. Lambert the *Schizaster* is a closer ally of the Tongrian *Sch. rimosus* than of the Aquitanian and Langhian species *Sch. desori.* Nevertheless, the evidence of these echinoids as a whole led me to regard them as Aquitanian, and Mr. Newton's identification of the associated mollusca agrees with that view. These echinoids were found in the limestones above the Fountain of Apollo at Ain Sciahat, and on the plateau east of Derna.

The third fauna includes the common but variable species of

---

[1] 'Éch. Foss. Sud des Hauts-Plat. Tunisie' Explorat. Sci. Tunisie, Paris, 1889, p. 91 & pl. vi, figs. 1–3.

Echinolampas, provisionally referred to as *E. chericherensis*. This species is widely scattered over the plateau east, west, and south of Cyrene, around Slonta and Messa, and it occurs nearly as far west as the Wadi Gharib; and a few specimens were found on the escarpment to the north of Cyrene. This fauna also includes *Scutella tenera* and a new species of *Amphiope*. Despite the presence of the last genus, the age of the fauna is probably Upper Eocene.

The lowest Echinoidea were found in the *Fibularia* Bed at the foot of the Cyrene escarpment and in a somewhat lower limestone containing many ecl[illegible] spines and scattered plates; both beds are Middle Eocene. [illegible] rocks, which on stratigraphical evidence, as well as that of the mollusca and foraminifera, are the oldest in Cyrenaica, yielded no determinable echinoids.

The geographical affinities of the fauna are with those of the Mediterranean Basin. The Upper Eocene (Priabonian) echinoids are found also in Tunis and Italy; the Aquitanian in Malta and Italy; the *Fibularia*, the one determinable Middle Eocene species, occurs in Egypt; but the rich Echinoid faunas of the Middle and Lower Eocene of Egypt are otherwise not represented in the collection. Their absence is probably due to the fact that the beds deposited during those periods in Cyrenaica were laid down in a deeper sea. None of the species of the corresponding beds in Western India have been recognized, although the faunas have certain features in common.

Depth of the Formations, as indicated by the Echinoidea.

The echinoid faunas show by the rarity of the massive Clypeasters,[1] common in many of the Mediterranean Oligocene and Miocene limestones, that the Cyrenaican rocks were deposited under somewhat deeper water than that in which the *Clypeaster* Beds of Malta and Italy were laid down.[2]

The approximate ranges in depth indicated by the echinoids for the formation of the limestones containing them would be from 10 to 50 (or perhaps 100) fathoms for the Miocene limestones east of Benghazi; probably not more than 150 or 200 fathoms for the *Echinolampas* Bed in the Priabonian; perhaps as much as 250 to 500 fathoms for the *Schizaster-ederi* and *Sarsella-lamberti* Bed at Cyrene. The *Fibularia* Marl might be deeper, as *F. australis* ranges down to 950 fathoms; and the absence of echinoids, except delicate spines, in the chalky beds of the Apollonia Limestones might indicate for those rocks a depth of perhaps 1000 fathoms.

---

[1] Fragments of a thick *Clypeaster* were found at Birlibah, Gubah, and in several exposures on the coastal plain about 12 to 15 miles east of Benghazi.

[2] The depth at which the massive *Clypeaster humilis* Ag. was obtained by the 'Challenger' ranged from 15 to 20 fathoms; see A. Agassiz, 'Report on the Echinoidea' Chall. Exped., Zool. vol. iii, pt. i (1881) p. 119. The range of *Clypeaster* and *Echinanthus* (*sensu* A. Agassiz) is given on p. 215 of the same Report, as down to 120 fathoms.

Fig. 1a.

Fig. 3.

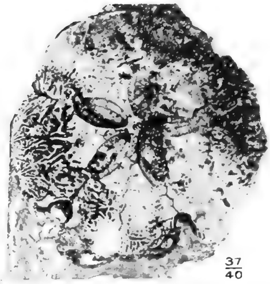


Fig. 2.

Fig. 1b.

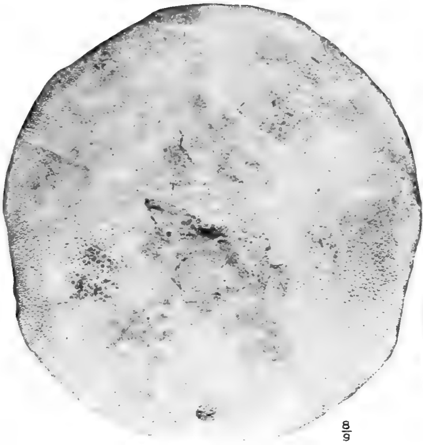


Fig. 4c.

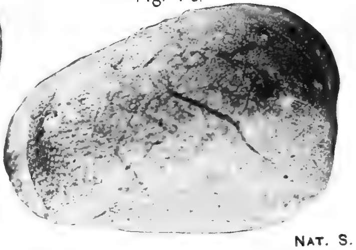


Fig. 4a.

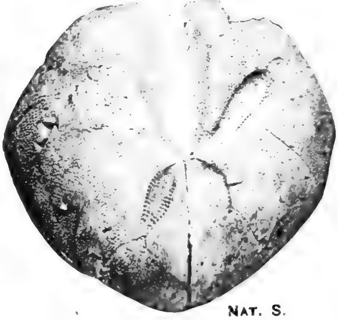
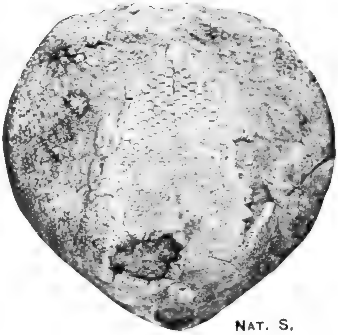


Fig. 4b.



J. Fingland, Photo. *Bemrose Ltd., Collo., Derby.*

ECHINOIDEA FROM CYRENAICA.

Fig. 1a. (Cy. 281) $\frac{57}{59}$

Fig. 1b. (slightly enlarged). (Cy. 281)

Fig. 2. (slightly reduced) $\frac{52}{55}$ (Cy. 217.)

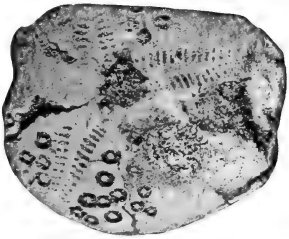


Fig. 3a.

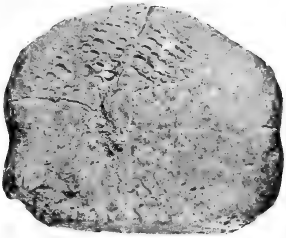


Fig. 3b.

J. Fingland, Photo.

Bemrose Ltd., Collo., Derby.

ECHINOIDEA FROM CYRENAICA.

Fig. 1b. (slightly enlarged). (Cy. 144).

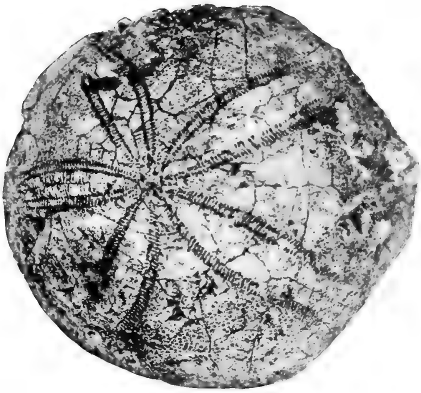


Fig. 2. (slightly reduced). $(\frac{55}{59})$. (Cy. 295).

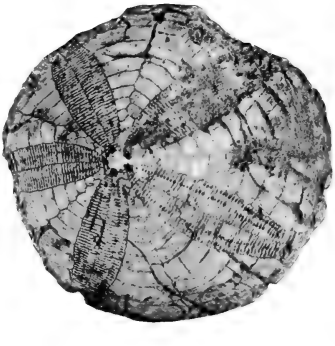


Fig. 3. (slightly reduced) $(\frac{44}{47})$ (Cy. 279).

Fig. 1a. (slightly reduced). (Cy. 144).

J. Fingland, Photo. *Bemrose Ltd., Collo., Derby.*

ECHINOIDEA FROM CYRENAICA.

EXPLANATION OF PLATES XLVII–XLIX.

PLATE XLVII.

Fig. 1. *Clypeaster biarritzensis* Cott., var. *trotteri*, nov. *Operculina* Limestone: Aquitanian. Half a mile east of Ain Sciahat. Fig. 1 *a*, the test from above; fig. 1 *b*, the test from below; both 8/9 nat. size. (Cy 98.) (See p. 662.)

2. *Amphiope duffi*, sp. nov. Slonta Limestone: Priabonian. Near Ain Sciahat, Cyrene. Natural size. (See p. 667.)

3. *Amphiope duffi*, sp. nov. Slonta Limestones at Sidi Rof Diasasia, south-east of Cyrene. Slightly reduced (37/40). (Cy 66.)

4. *Schizaster ederi*, sp. nov. *Operculina* Limestone: Aquitanian. Ain Sciahat, Cyrene. Fig. 4 *a*, specimen from above; fig. 4 *b*, from below; fig. 4 *c*, from the side; natural size. (Cy 100.) (See p. 674.)

PLATE XLVIII.

Fig. 1. *Echinolampas chericherensis* Gauth. A specimen of var. *a* from Messa. Fig. 1 *a*, seen from above, slightly reduced (57/59); fig. 1 *b*, the same from the side, slightly enlarged. (Cy 281.) (See p. 669.)

2. The lower surface of a specimen of var. *b*. Slonta Limestone: Priabonian. East of Messa. Slightly reduced (52/55). (Cy 217.)

3. *Sarsella lamberti* sp. nov. *Operculina* Limestone: Aquitanian. Near Ain Sciahat, Cyrene. Fig. 3 *a*, specimen seen from above; fig. 3 *b*, from below; slightly reduced (37/42). (Cy 274.) (See p. 675.)

PLATE XLIX.

Fig. 1. *Echinolampas chericherensis* Gauth. A specimen of var. *b* from the Wadi Jeraib, east of Gasr el Migdum. Fig. 1 *a*, the lower side slightly reduced (55/57); fig. 1 *b*, the same from the side, slightly enlarged. (Cy 144.) (See p. 670.)

2. The uppermost surface of a specimen of var. *a*. Slonta Limestones. Slightly reduced (55/59). (Cy 295). (See p. 670.)

3. Specimen of a variety from the Wadi Firyah. Slightly reduced (44/47). (Cy 279.) (See p. 670.)

DISCUSSION.

Dr. C. W. ANDREWS congratulated the Authors on this valuable contribution to our knowledge of the geology of a little-explored district, and remarked that the suggestion that Crete was connected with the mainland in late Pliocene or early Pleistocene times was supported by the discovery by Miss Bate, on that island, of *Elephas antiquus*, a dwarf elephant (*E. creticus*), and a *Hippopotamus* near to *H. pentlandi*.

Dr. TEALL referred to the approximate horizontality of the Eocene beds over large areas both in Cyrenaica and in Egypt, and to the great difference of level of corresponding members of this formation in the two regions. He asked Prof. Gregory whether he had formed any opinion as to how this difference in level was to be accounted for. Had the whole of the vast Egyptian area been lowered by faults of the kind to which reference had been made? He (the speaker) thought that the paper was of great interest in connexion with the tectonic features of the eastern half of the Mediterranean area.

Mr. A. WADE said that he was glad that the paper furnished another link connecting Egyptian geology with that of other

Mediterranean areas. He noted with interest the close structural and palæontological connexions. The main lines were apparently similar to those which affected the areas bordering the Red Sea, as well as the districts surrounding the Eastern Mediterranean. He noted also with satisfaction the further evidence of an extension of a North African land-area in Middle Tertiary times. The chain of evidence had now been carried from Western Egypt, through Cyrenaica, Crete, and Cyprus, and probably farther eastwards.

Prof. GREGORY explained that he had searched for terrestrial deposits, but the whole series was of marine origin; and any western continuation of the terrestrial Upper Eocene beds of Egypt must be looked for to the south of the area that he had visited.

The Cyrenaican fractures were part of a series which had affected a vast area south and south-east of the fold-mountains of the Atlas and the Apennines. The Cyrenaican beds had a gentle dip to the east, and the country might be described as part of one limb of the geosyncline of Western Egypt; but the lowering of the Miocene limestone from the summit of the plateau of Cyrenaica to sea-level on the Libyan coast, and of the Derna Limestone (the representative of the Mokattam Series) to a low level in Egypt was aided by a succession of step-faults. In regard to the problem raised by Dr. Teall, he agreed with Suess that the difference in level could be better explained by the subsidence of Egypt, rather than by the uplift of Cyrenaica.

19. *On the* GEOLOGY *of* ANTIGUA *and other* WEST INDIAN ISLANDS *with reference to the* PHYSICAL HISTORY *of the* CARIBEAN REGION. By R. J. LECHMERE GUPPY. (Communicated by Prof. E. J. GARWOOD, M.A., Sec.G.S. Read May 24th, 1911.)

[PLATE L—MAP.]

CONTENTS.

I. INTRODUCTION.

MY paper on the 'Geological Connexions of the Caribean Region'[1] dealt as a whole with the Atlantis Problem and the changes on the earth connected therewith. Among other matters, I indicated the course of the dislocation (which I will call the great Antillean Dislocation) passing along the chain of the Antilles from Trinidad to Sombrero, and thence as I suggested through the northern part of the Island of Haiti. To make such further observations as were possible to me despite my physical disabilities, I undertook a voyage to Antigua and the neighbouring islands in the early part of 1910.

In the preparation of this paper I have consulted all the authorities available to me, but I have made most use of the papers by Purves and Spencer. For Dr. J. W. Spencer's papers I am indebted to himself, and for Purves's I am indebted to the Natural History Society of Belgium.

II. CONSIDERATIONS ON THE GEOLOGY OF ANTIGUA.

Geologists and all interested in West Indian geology owe much to men who, like Nugent (a resident) and Purves (a visitor), undertake to furnish a careful and conscientious account of the features of a neglected and despised island such as Antigua. High praise is due to them. In the time of Nugent (1819) geological science was in a backward state, and he did not therefore enjoy the means that his successor possessed of dealing with geological subjects. Yet Nugent's work is the basis of our knowledge of the geology of Antigua. He was followed by J. C. Purves, whose memoir was published in the Bull. Mus. Roy. Hist. Nat. Belg. vol. iii (1884–85) p. 273. Any one who has an idea of what it is to explore geologically a tropical island must feel grateful to Purves for his elaborate and conscientious survey. Nevertheless, in such cases there is

---

[1] Trans. Canad. Inst. vol. viii (1908–1909) p. 373.

always room for expansion and correction, and it is not possible for any observer, however honest and painstaking, to cover without error all the problems which present themselves, and to grasp immediately the bearing of the features which come into view. My short visit to Antigua revealed to me how ably the work of Purves had been done, but my physical incapacities would certainly have prevented me from adding anything of my own, had it not been for the kindly aid of Mr. W. R. Forrest, a gentleman whose amiable disposition, combined with his enthusiasm for the study of nature, induced him to assist me. Therefore, it is to him that I owe the possibility of presenting the following notes, which are merely remarks on and deductions from the observations of Purves and Spencer.

Dr. Spencer's work is based on Purves's; but, for convenience, I refer here to Spencer's. His section[1] across Antigua shows the strata in the following order (omitting minor details):—

(1) Old igneous basement = South-Western Region.

(2) Tuff series, with layers of marine cherty limestones and also freshwater cherty beds. } = Central Plain.

(3) White Limestone Series = Antigua Formation.

An orderly and apparently conformable succession of these rocks is here exhibited, each set underlying the next one in the order stated, so that the White Limestone appears to overlie the Tuff Series, which in its turn is superior to the igneous series. Purves describes these rocks very fully, and Dr. Spencer gives a summary of his description, remarking that there is nothing in the character of the volcanic or igneous rock to establish its age, which must (he says) be pre-Tertiary because it underlies Tertiary deposits. My conclusions on this point will be gathered from what follows.

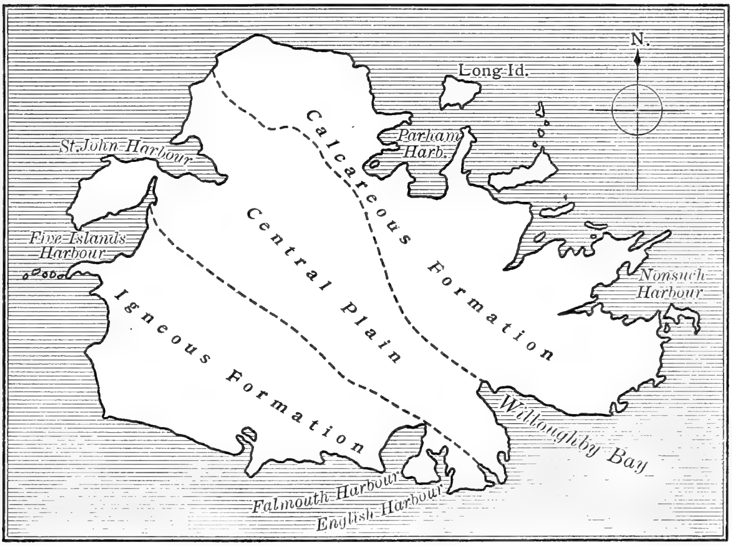
It is admitted that the surface of Antigua is divided physically into three regions, of which the boundaries run approximately from north-west to south-east. Of these regions the south-western one is igneous, while the north-eastern one is calcareous and sedimentary. The middle portion between these two regions is a depression called the 'Central Plain,' out of which rise several hills. It may be broadly stated that the first-named or igneous region is a mass of hills formed of volcanic craters and their ejectamenta, and that they are for the most part covered by tuffs consisting of such ejectamenta. All these are fully described by Purves and Spencer, and the only observation that I would add on this point is that I believe the ejectamenta to have been mostly subaërial and to have been thrown out of the volcanic vents, forming layers which present a stratified appearance, just as is the case with the similar deposits of Mont Pelé in Martinique and elsewhere. The effect of heated gases and percolating water has been to consolidate these tuffs more or less, and in varying degrees.

---

[1] Q. J. G. S. vol. lvii (1901) p. 492.

The north-eastern region consists mainly of a calcareous formation called by Dr. Spencer the Antigua Formation. He identifies with it the White Limestone of Barbuda, St. Martin, and Guadeloupe, and calls it 'Oligocene.' It is generally a chalky rock, varying much in hardness and coherence, and containing numerous casts of mollusca and other fossils. At a marl-pit about 2 miles from St. John, to which Mr. Forrest took me, I found this rock to contain many fossils, one of which was a *Pholadomya*: there were also casts of a *Turritella*. This rock was full of small *Orbitoides*. I did not detect other foraminifera or radiolaria. Proceeding to Hodge's Bay on the north of the island, we found a similar rock exposed on the shore, and containing *Orbitoides* measuring between 2 and 3 inches in diameter, and many Pectens; but we failed to extract entire specimens. The large size and peculiar condition of the *Orbitoides* made me somewhat doubtful about them, and my workshop and library not being at hand I could not verify the determination; but afterwards Dr. Lang, of the British Museum (Natural History), was good enough to examine them and to give me his opinion that they were truly *Orbitoides (mantellii)* as previously determined by the late Prof. T. Rupert Jones. Some portions of this rock were almost entirely composed of the smaller *Orbitoides*, being in this respect quite similar to the *Orbitoides* Bed of Naparima (Trinidad),

Fig. 1.—*Outline-map of Antigua, to show the inlets, etc. on the scale of 6 miles to the inch.*



though in the latter only small *Orbitoides* have been found.[1] Owing to this resemblance, I feel convinced that other fossils, especially fish-remains and echinodermata, will be found in this rock.

P. Martin Duncan and T. Rupert Jones wrote in the 'Geological Magazine' for 1864 on the fossils and geology of Antigua (pp. 97, 102). Their papers were based on the information supplied by Nugent. In my 'Second Note on the Manjak Mine' (Trinidad, 1909) I have quoted from Rupert Jones's paper on the *Orbitoides* of Antigua to show that they are essentially the same as those of Trinidad. Duncan's and Jones's papers were written long before the time of Purves: their principal object was the chronological correlation of the Tertiary strata of Malta and Antigua. The *Orbitoides* had a great share in this correlation. So far as the relative age of the Antiguan and Maltese strata goes, the above-mentioned writers may be said to have made out a case; but the assignment of the Antigua Formation to the Miocene must, I think, in view of our present more definite knowledge, be given up. In the discussion which followed the reading of my paper on the Microzoic Formations of Trinidad,[2] Vaughan Jennings remarked that the difficulty (of determining the age of West-Indian formations) was due to the want of 'accurately-localized specimens and stratigraphical horizon.' Hence we find *Orbitoides* recorded from the 'Miocene' or 'Oligocene,' although it is probable that they came from underlying or neighbouring beds. In Dr. Spencer's paper on Cuba certain identifications of fossils are ascribed to me, and I believe this is correct. But, being unacquainted with the deposits, I fear that I followed my predecessors too blindly, and did not so carefully discriminate between fossils from different formations as I ought to have done. I can, however, aver that personally I have never found *Orbitoides* associated with the truly characteristic Miocene mollusca. It was the differences that I observed between the faunas of the different beds in Trinidad that induced me gradually and tentatively to assign a more ancient date to certain strata. And I think that further observations are needed to clear up the alleged occurrence of *Orbitoides* in Miocene strata in Haiti, Jamaica, and other islands.

This may possibly be a suitable occasion for me to say a few more words on the correlation of West Indian deposits of Tertiary age. Even so eminent a Professor as J. W. Gregory has fallen into the common error of mixing up the Miocene with the Eocene, and calling the result 'Oligocene.' In his paper of 1895[3] he refers to two echinoids, sent to him from Antigua as coming from the 'Oligocene' of that island. Of these, *Echinanthus antillarum* is stated by Cotteau to be an Eocene species from St. Barts; while

---

[1] I have found some 'large thin' Orbitoides in the *Orbitoides* Bed of Trinidad, but the largest of these is only 12 millimetres in diameter, whereas the Antiguan specimens are 60 mm. in diameter and possibly even larger than this.

[2] Q. J. G. S. vol. xlviii (1892) p. 541.

[3] *Ibid.* vol. li, p. 295.

the other, *Clypeaster concavus* Cot., is stated to be from the Miocene of Anguilla, having been previously recorded by me from that island under the name of *Cl. ellipticus*. Some mistake must have crept in here, for at any rate the St. Barts formation is definitely assigned to the Eocene, while that of Anguilla is considered to be Miocene. I am the more inclined to suspect a mistake as to the distribution of the fossils, because I find that *Echinolampas semiorbis*, which I described from the Miocene of Anguilla, has been assigned by Cotteau to the Eocene of St. Barts. The error is a serious one, because Cotteau also cites *E. semiorbis* from Cuba, and much confusion has already arisen in regard to the classification and arrangement of West-Indian strata, owing to the want of due care in stating the exact localities of fossils. I might note here that *Brissus exiguus* Cotteau, a fossil originally described from Anguilla, has lately been obtained from Miocene beds in Trinidad associated with the characteristic fossils of that formation.

R. T. Hill[1] discusses the question of the occurrence in the Antilles of Eocene deposits, and remarks that

> 'all geologic record of the lands whence the Antillean [Eocene] deposits came are destroyed.'

He accepts the Eocene age of the St. Barts beds, but puts the Anguilla beds with them. Now the latter contain characteristic Miocene mollusca, while the echinodermatan fauna is different from that of the Eocene. He alludes to the *Orbitoides* and *Nummulinæ* of Antigua as probably Eocene, and decides that certain beds in Haiti are also of that age; and he quotes Tippenhauer in support of this view. He makes no doubt of the Eocene age of certain beds in Cuba.

Although W. M. Gabb refers to the occurrence of *Orbitoides*[2] as having helped him to discriminate between the beds which he assigned to the Miocene and to the Pliocene respectively, yet in the numerous cases where he names the characteristic Miocene mollusca he does not mention *Orbitoides*, and where he does mention it he refrains from asserting the coexistence of Miocene mollusca with it. It is unfortunate in this connexion that the mollusca of the Eocene deposits are so seldom found in a condition admitting of specific determination or description. The name of *Natica phasianelloides* is given from several localities as that of an Eocene and Miocene fossil; but the imperfect state of the specimens does not preclude the possibility that some may belong to another species. A fossil apparently the same, from the Tejon (Eocene) Beds of California, has been figured under the name of *Amauropsis alveata* Conr. in U.S. Geol. Surv. Bull. 396 (1909) pl. iv, fig. 21.

While claiming for the calcareous formation of Antigua (called

---

[1] 'Geology & Physical Geography of Jamaica' Bull. Mus. Comp. Zool. Harvard, vol. xxxiv (1899) p. 177.

[2] 'Geology of Santo Domingo' Trans. Am. Phil. Soc. vol. xv (1873) pp. 96, 167, 174.

by Dr. Spencer the Antigua Formation) an antiquity not less than Eocene (for it is probably of the same date as the *Orbitoides* Bed of Trinidad), I do not assert that all the formations correlated with it are as old. We have sufficient reason for assuming the strata containing *Echinolampas ovum-serpentis* and *Terebratula carneoides* in St. Barts to be of that age. It is denied that any Miocene deposits exist in St. Barts; but the strata of Anguilla containing *Echinolampas semiorbis* and *E. lycopersicus* are reasonably considered to be Miocene.[1] Nevertheless, it is probable that Miocene as well as Eocene strata are developed along the course of the Antillean dislocation, and moreover that the formations found along the Lavega Plain in Haiti contain Eocene as well as Miocene strata. The same has been shown by Mr. G. P. Wall to be the case with the Cumana or Cariaco depression in Venezuela,[2] but we still require more evidence on this point from carefully-collected fossils. Casts of fossils are common in many of these formations, and they simulate equally early Mesozoic and late Tertiary or even recent shells: the inferences drawn from them are therefore misleading, as I can state from personal experience, and as may be seen by reference to many geological papers where Eocene and Miocene fossils in the shape of casts are identified with living species.

To go into the question of the bearing of the fossil corals of Antigua upon the age of the formations of that island would lead me into an enquiry too complicated for the present occasion. So far as I can make out from a perusal of P. Martin Duncan's papers and of Purves's and Gregory's observations thereon, the evidence is uncertain; but doubtless further light will be thrown upon the question by renewed investigation.

We must now consider the middle region of Antigua, that designated the 'Central Plain'; this name can hardly be said to be appropriate, as the 'Plain' is not only uneven generally, but several hills rise in a more or less interrupted and irregular range along the middle part of it. The formations of which the 'Central Plain' is composed are fully described by Purves, who represents them as a series of beds of tuff among which are intercalated deposits of chert and limestone containing terrestrial and freshwater shells and silicified wood and corals. There is a marine chert, as well as a freshwater chert; but for details I must refer the reader to Purves's paper. The important conclusion arrived at by him is contained in these words:—

'La région volcanique qui s'étend depuis les bords méridionaux du Lac Taupo jusqu'au delà de la contrée lacustre autour de Tarawera...... est certainement celle qui présente actuellement les conditions les plus analogues à celles dans lesquelles s'est formé le chert d'Antigoa. Cette région repose sur un fond de tuf trachytique et de congloméré, à la surface desquels sont disséminés de nombreux lacs, marais et lagunes au milieu et sur les bords desquels jaillissent des milliers de sources bouillantes, fortement chargées de silice

---

[1] The Miocene age of the Anguilla formation is confirmed by the evidence which the fossil mollusca supply. See Q. J. G. S. vol. xxii (1866) p. 574.

[2] See Trans. Canad. Inst. vol. viii (1908–1909) p. 378.

qu'elles déposent en se refroidissant en vastes nappes de roches affectant la texture du silex et de la calcédoine.' (Bull. Mus. Roy. Hist. Nat. Belg. vol. iii, 1884–85, p. 300.)

Both Purves and Spencer in the diagrams given in their papers have represented the 'stratified tuffs,' that is the formations of the 'Central Plain,' as passing under the Calcareous or Antigua Formation, which is thus made to overlie these tuffs. But this is purely hypothetical, and I do not think that it is borne out by the evidence. I doubt whether the contact between these formations is anywhere observable. It is much more probable that the tuffs abut against the upraised edges of the calcareous beds, but any such junction is hidden by the tuffs and volcanic débris of the 'Central Plain.' It is likely that the volcanic formations of the tuffs, and the marine and freshwater cherts, etc., are younger than the calcareous beds of the Antigua Formation. The specimen of *Orbitoides* said to have been found in the chert may easily have been derived from the adjoining calcareous rocks of older date. And, although the fossil corals of Antigua were considered by Duncan to have generally preponderating Miocene affinities, there is no certainty on this point. Many of them, indeed, came from the chert, and his ideas regarding the geology of the island, based on the information supplied by Nugent, are entirely supplanted by Purves's observations.[1]

The Antigua Formation is of a very Cretaceous aspect, containing *Orbitoides* in vast numbers and of a high degree of development, and its other organic remains are not inconsistent with the theory of a late Cretaceous age for it. A circumstance that might induce one to pause before regarding the formation of the 'Central Plain' as more ancient than the Antigua Formation, is the extremely modern aspect of the fauna of the freshwater chert as enumerated by Purves. Even though some of the species are said not to be now living in Antigua, yet it is doubtful whether they can be distinguished from West Indian living forms. The list of fossils comprises four freshwater shells, two terrestrial shells, and two so-called amphibious shells. The last-named, *Melampus* and *Truncatella*, are never found in the water, and only within reach of the salt spray and in sheltered places. *Melampus* lives in the crevices of rocks above high-water mark; *Truncatella* lives on the ground above high-water mark, among pebbles and weeds. These molluscs cannot live in water, and they, as well as the other mollusca, were no doubt drowned in the hot siliceous waters of the Central Plain—hence the preservation of the soft parts in the shape of silicified casts, as described by Purves. The identification of the shell ascribed to *Pomatias* is uncertain; it is more likely a *Tudora* or a *Cistula*, such as now inhabit Anguilla and the neighbouring islands. As regards the *Nematura*, which is another case of uncertainty, for it is admitted that it might be an *Amnicola* (a genus common in all the West-Indian islands), it would be nothing extraordinary, even were it rightly identified, for we have *Helix labyrinthica* at the same time

---

[1] P. M. Duncan, Q. J. G. S. vol. xix (1863) p. 410.

fossil in the Eocene of Europe and living in America even as far south as Venezuela. Again, there is *Cyrena semistriata*, a fossil of the European Eocene also found fossil in late Tertiary beds in Trinidad, and scarcely distinguishable from the living *C. solida* of Central American rivers. Still these facts, although suggestive, cannot be regarded as conclusive, for it is quite conceivable that the freshwater chert might be (as it probably is) a later formation than the rest of the Central Plain. We must, therefore, enquire what aid we can obtain elsewhere in determining the relative ages of the formations of Antigua.

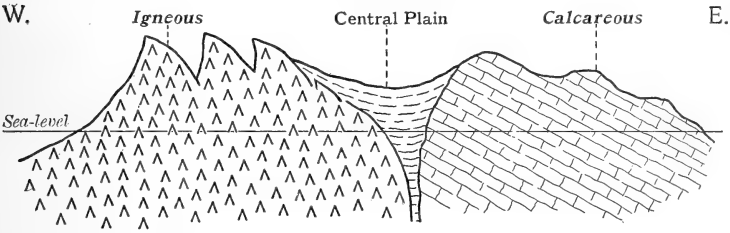
In order that what follows may be more easily understood, I may state briefly the conclusion at which I have arrived in reference to this 'Central Plain.' The course of the great Antillean Dislocation is shown in my paper already mentioned (Trans. Canad. Inst. vol. viii, 1908–1909) by a curve extending from the Gulf of Cariaco in Venezuela through the Gulf of Paria, and thence along the line of the Antilles between St. Vincent, etc. and Barbados, and thence northwards, turning to the west near the Virgin Islands. In the north-eastern part of its course there are two points where the dislocation shows itself above the sea-level, the remainder of this part of its course being under water and inaccessible to observation except by sounding. The two points referred to are Guadeloupe and Antigua. This great fault, fissure, or dislocation divided the island of Guadeloupe into two portions, the division between the two portions being marked by a narrow channel called the Salt River. Farther north it divided the Island of Antigua also into two portions, the 'Central Plain' of Antigua being situated upon the very fissure itself, widened by the breaking-away of its edges and filled in by the materials derived from the fracture and degradation of the neighbouring rocks. It is not accurate to say that these islands were divided by the dislocation; they are really the product of the dislocation: for, while on the western side of the fissure immense volcanic activities were brought into play, producing the chain of the Lesser Antilles, the sea-bottom on the eastern side was elevated and even everted, bringing up above water in a few places the Cretaceous and Tertiary deposits formed along the margin of the Atlantis Continent, while the continent itself was sinking. In the case of Barbados, an offshoot eastwards of the main dislocation elevated that island, but produced no volcanic phenomena in its neighbourhood.

In the map appended to my Canadian Institute paper the draughtsman omitted Antigua and the small islands in its neighbourhood. The sketch-plan (Pl. L) which I now present shows on a larger scale than that map, and better than a verbal description could show, the probable approximate line of dislocation. The accompanying diagrams (fig. 2, p. 689), though not drawn to any scale, give an accurate idea of the relations of the dislocation to the surrounding formations. The first two of these diagrams (*a*) & (*b*) are, of course, founded on actual observation; but the third (*c*),

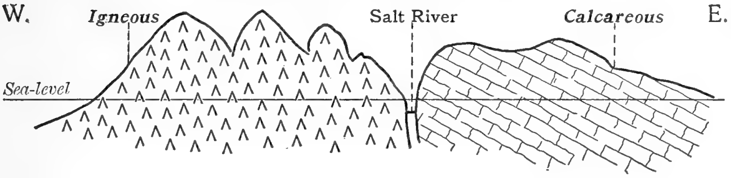
which represents a section of the dislocation in its course between the islands, is hypothetical, as we are unable to get to the bottom of the sea to investigate the strata there. I have not in these diagrams indicated the numerous volcanic openings through which the ejectamenta composing the islands came; but I assume that it will be understood that, speaking generally, the line of fissure which I have marked is the eastern edge of a broken and dislocated area, the width of which was variable and is now occupied by the volcanic formations.

Fig. 2.—*Diagrammatic sections across the Antillean Dislocation.*

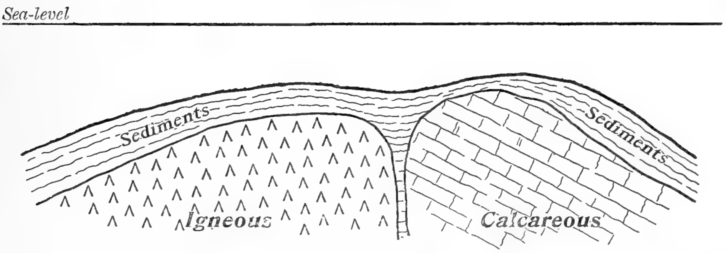
(a) Above sea-level (Antigua)



(b) Above sea-level (Guadeloupe)



(c) Below sea-level



Purves notices the numerous inlets, bays, gulfs, and creeks that diversify the coasts of Antigua. Dr. Spencer, in accordance with his theories of sunken valleys and a drowned Antillean Continent, emphasizes those features of the island and attributes them mainly to subaërial erosion. He says[1] that the prolonged denudation has

---

[1] Q. J. G. S. vol. lvii (1901) p. 493.

largely given rise to the physical features of the island. But, in reality, the physical features of Antigua are mainly due to the causes which I am about to mention, and denudation has played quite a subordinate part in shaping the features of the island. I have seen the effects of erosion, marine and fluvial, in many parts of the world (for example, in New Zealand, Switzerland, Italy, etc., not to mention the coasts of England and Wales); but I could not assimilate the features of Antigua to any of them. The Bocas or channels at the entrance of the Gulf of Paria are good examples of submerged valleys, which have been immensely enlarged by marine erosion. Near them are sunken valleys which have not been so enlarged. But none of them in any way resemble these inlets of Antigua. Leaving aside for a moment the question of whether the line of the Antilles is a submerged region, there are several considerations adverse to the conclusion that these inlets are due to denudation. The north-eastern coast of the island is full of inlets and creeks with numerous islets, shoals, and banks of all sizes. But there are no rivers in this region, which is that of the Calcareous Formation. It is probable that the numerous irregularities of this coast are produced by the solution of the rocks, the waters both meteoric and marine attacking and dissolving the more soluble and less coherent beds, thus eating away the land in an irregular and uneven contour. Simple marine erosion has usually a tendency, except where the rocks are of unequal consistency, to reduce the shore to a straight line. Fluvial erosion, other than that due to solution of calcareous matter, is absent from this region.

We now take the case of the large inlets (see fig. 1, p. 683) known as Falmouth, English Harbour, and Five-Islands Harbour, which are in the Igneous Formation. They are large excavations, quite different in shape from subaërial valleys. There is absolutely no room in Antigua, even were the rainfall increased tenfold, for the rivers that would be required to excavate such valleys. The raising of the land 600 feet higher, that is to the 100-fathom line, would greatly enlarge the island, so that it would form one with Barbuda. But this would not affect the question: for the rivers, even if any could exist upon such land, the greater part of which would be porous calcareous formations, would from their position have no effect upon the supposed sunken valleys. The conclusion is irresistible: these inlets are the remnants of volcanic craters, and the immense quantities of matter ejected from these craters can be seen all around in layers and beds on the adjacent hills.[1]

The remaining large inlets, namely the Harbour of St. John and Willoughby Bay, are situated one at each end of the Central Plain, and here their origin is plain enough: they are simply portions of the fissure along the line of the great Antillean Dislocation. They are

---

[1] In papers written some years ago (1902 and previously) I mentioned that the harbours of Kingston (St. Vincent), Castries (St. Lucia), and St. George (Grenada) were volcanic craters.

both situated on the same line and in the same depression, and it is impossible that any rivers capable of excavating such valleys could be developed in a small space measuring about a dozen miles in length by 3 or 4 in width. To meet the conditions there must have been two such rivers running in opposite directions. This depression (the 'Central Plain') is hemmed in on the east by the calcareous formations, and on the west by the hills of the Volcanic Series; and there is no other land which could have supplied such rivers. What astonishes me here is that previous observers who investigated the physical features of Antigua did not at once perceive the significance of these two inlets and the depression between them, marking plainly the division between the volcanic region on the one hand and the sedimentary region on the other.

It is not probable that Antigua was ever 1000 feet higher than it is now, even if it was ever much higher at all. The belt of the Antilles is rather an elevated than a sunken region. It is unlikely, therefore, that any drowned subaërial valleys should exist in this area. The sunken region of Atlantis lay to the east of the Antilles. The calcareous islands are not remnants of land, but remnants of marine formations laid down off the margins of the ancient Atlantis, and their upheaval was more or less simultaneous with the sinking of that land.

It is possible that the Island of Antigua marks a point where the subterranean forces assumed a maximum of intensity; for there the extent of the upheaval was greater than elsewhere, and resulted in the formation of the 'Central Plain' above sea-level and upon the fissure itself. This 'Central Plain' thus became the theatre of an immense development of lakes and hot springs, similar to those of the North Island of New Zealand. The volcanic vents of Drewhill and Boon Point supply an indication of the intensity of the eruptions, upon and even to the east of the fissure. In the case of Guadeloupe the edges of the fissure rose above sea-level; but a 'Central Plain' with its extraordinary development of lakes, etc., did not arise here. In other parts the fissure was entirely under water, and is largely filled up by the sediments from the adjoining islands. The points of greatest intensity of the volcanic disturbances are those marked by the Antillean islands, and at intermediate points it seems unlikely that any developments of vulcanicity took place upon the actual fissure or line of dislocation.

The phenomena which I have endeavoured to elucidate in this paper will probably serve as a key to some of those exhibited in Haiti and other islands of the Greater Antilles; but, as I am unable to pursue the investigation, I must leave it to my successors to follow it up. I think it highly probable that the Lavega depression in the island of Haiti, among others of a like kind, will be found to resemble in some respects the 'Central Plain' of Antigua.

There are other points upon which I might dwell in favour of the theory here propounded, but I think that what has been set

forth in these pages will commend itself to all who consider the matter carefully. I will, however, offer a passing allusion to one other point. Purves says of the Calcareous Formation:—

> 'La puissance de cette vaste formation calcaire indique qu'elle s'est déposée pendant une longue période d'affaissement du sol qui a suivi l'extinction de l'activité volcanique.' (Bull. Mus. Roy. Hist. Nat. Belg. vol. iii, 1884–85, p. 307.)

For this to be true the island must have been sunk below the sea-level for an immense period after the cessation of volcanic activity, so as to permit the deposition upon it of a great calcareous formation. Unless we suppose the relative levels of the different parts of the island to have been greatly altered, the whole of it (including, of course, the Central Plain, with its marine and freshwater cherts and limestones) must have been submerged and subsequently re-elevated. And, in such a case, how is it that the Calcareous Formation was confined to one area instead of extending over the whole island? But there is absolutely no evidence for any such submergence and re-elevation, which must have left traces of some kind upon the volcanic formations; these, however, are intact, and, allowing for denudation, in the same state now as when the volcanic forces ceased their activity, nor do they show any signs of ever having been submerged. But, if we suppose as my theory requires, that the Calcareous Formation is older than, and was upheaved at the time of, the volcanic disturbances, all difficulty vanishes, for this explanation is in accordance with the facts as we see them. And this leads to a further suggestion, which is that the volcanic disturbances occurred during the Miocene Period and after the deposition of the Cretaceous and Eocene strata, and probably continued during the whole of that Period. Further, during that Period the oceanic deposits were accumulating in the deeper parts of the West Indian area, to be gradually upheaved in places during the progress of the volcanic disturbances which accompanied the sinking of Atlantis.

III. Considerations on the Geology of Barbados.

The same physical inabilities that beset me in Antigua also followed me to Barbados; but, here as there, I had the good-luck to find friends to assist me. Mr. Percy Haynes took me in his carriage from Bathsheba, where I stayed, to Bissex Hill which we visited together. My object there was to examine the Foraminiferal Marl; but the exposure of it was insufficient, and the material was too weathered to be of much use for my purposes. Mr. Haynes gave me some specimens of sharks' teeth (*Carcharodon* and *Lamna*), a cast of a *Pleurotomaria*, and a specimen of *Echinolampas anguillæ* Cot. (= *E. lycopersicus* var.), now first recorded from Barbados: these came from the marls of Bissex Hill. I examined a sample of these marls, and found it to consist mainly of small *Globigerinæ* with a few other foraminifera, of which the most

conspicuous was *Uvigerina (Sagrina) raphanus,* common in the Sangregrande Beds of Trinidad.

Of course, in Barbados I had no more idea of competing with those excellent observers, Prof. J. B. Harrison and Mr. A. J. Jukes-Browne, than I had in Antigua of rivalling Nugent and Purves. I only made use of their work, in so far as it helped me to elucidate the particular points which I had under consideration; and my work is merely supplementary to theirs, so far as it may be admitted to be valid.

Mr. Labastide, Manager of the railway, took me on his trolly as far south as Bath and as far north as St. Andrew, thus enabling me to inspect the strata of the Scotland district exposed along the line. In Trinidad the *Orbitoides* Bed is found below the manjak-deposits. And so in Barbados I procured samples of 'black sand' from the manjak and petroleum-deposits. But I found no *Orbitoides*, either here or elsewhere in Barbados. What I thought was black sand turned out on examination to be radiolarian rock containing a very high proportion of carbonaceous matter, in fact petroleum. There were a couple of foraminifera, namely, a small Rotaline and a *Uvigerina*, but the bulk of what I had taken to be sand was a mass of radiolaria. It is not to be supposed that petroleum originated in the deep and clear water required for radiolaria. I presume, therefore, that the petroleum has percolated into the radiolarian rock from other deposits.

In this part of Barbados the strata underlying the coral-rock being, as the Oceanic Beds usually are, of yielding materials, are readily loosened and carried off by the springs which break out from under the coral-rock. Thus a gradual slipping-forward of the whole region is induced, forming a kind of undercliff. Prof. Harrison and Mr. Jukes-Browne do not seem to think that the coral-rock, which forms an almost continuous sheet over the Island of Barbados, ever completely covered the Scotland district. The rocks named the Scotland Beds are chiefly exposed in this region, and it was to these that I turned my attention. These rocks are stated by Prof. Harrison and Mr. Jukes-Browne to consist of thickly-bedded sandstones, coarse grits, etc. In their report on the 'Geology of Barbados,'[1] they say that the Scotland Series is a shallow-water formation, owing its origin to the detritus carried down by the rivers running off a land that was composed of quartz-bearing rocks. At Chalky Mount I saw a coarse conglomerate, the pebbles in which are of some size and are derived from a schistose or clay-slate formation, such as is found in the northern parts of Venezuela and in Trinidad. Some of the conglomerates were of quartzose pebbles and sand, while others contained pebbles of clay-slate; and I thought that they bore a stronger resemblance to fluviatile than to marine deposits, although it is possible that some beaches under or near cliffs might be similar. But there is no rock in Barbados whence such pebbles

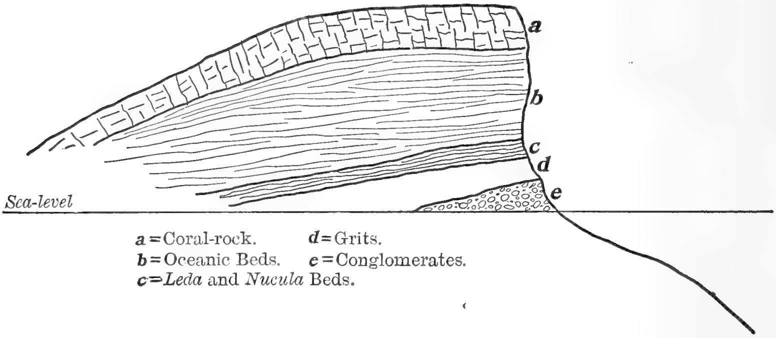
---

[1] Published by authority of the Barbadian Legislature, 1890, pp. 11 & 36.

could have been derived. I append a diagram (fig. 3) showing my view of the strata of the Scotland district before the removal of a large part of them by denudation.

Dr. Spencer[1] takes a somewhat similar view of the age of the Scotland Beds, but he thinks that the material was derived from the Orinoco. That river, however, was not in existence at the time, and we need hardly go so far, not to speak of the difficulty of transporting quantities of large and heavy pebbles across the intervening space. The northern portion of South America lying between the parallels of 10° and 12° lat. N., now partly submerged, was nearer and was then above water. But it is more probable that it was Atlantis itself that was the source of this material.

Fig. 3.—*Diagram of strata originally exposed at Chalky Mount (Barbados).*



[Great part of the strata represented in this figure has been removed by denudation.]

I think, therefore, that while in Antigua and elsewhere formations occur belonging to the sea-margins of Atlantis, we have in Barbados an actual fragment of that continent itself. This statement applies principally to the lower conglomerates and coarse grits of the Scotland Series, which I should consider to be Cretaceous. The upper part containing fossils, among others the *Leda* and *Nucula* described by Forbes in Schomburgk's History, may be Eocene; though I have shown (in Proc. Sci. Assoc. Trinidad, 1878, p. 170) that the *Nucula* is nearly allied to *N. bivirgata* of the Gault.

I am somewhat puzzled by the list of fossils tabulated by Prof. J. W. Gregory[2]; and I should not like to express any opinion thereon, unless I knew more about them and about the beds from which they came.

---

[1] Q. J. G. S. vol. lviii (1902) p. 357.

[2] *Ibid.* vol. li (1895) p. 310.

IV. The Parian Subcontinent.

To the north of the South American continent lies a sea having a depth which does not exceed 600 feet. This area, bounded on the north by a line approximately parallel with the coast of Venezuela, extends as far east as long. 60° W. It is a sea full of rocks, shoals, and islands including Tobago, and is partly indicated in Dr. Spencer's map.[1] It is probable that during the Miocene Period this area was dry land, and this land now drowned, together with the northern part of Venezuela as far south as the Llanos of the Orinoco, I propose to call the Parian Subcontinent. It is remarkable that, from the point where the line of the great Antillean Dislocation enters upon this area, no evidences of vulcanicity appear in the neighbourhood of it. The line of dislocation itself is well shown by the soundings which are deeper along its course than elsewhere.[2] Dr. Spencer has indicated it as one of his drowned valleys, and makes it run towards the north; but I have shown[3] that the valleys parallel to and in the neighbourhood of this all run southwards. In the Gulf of Paria the dislocation reached a maximum, for that Gulf is due to it. Here it divided and turned westwards, passing through the Gulf of Cariaco, which is also due to it. Is it possible that the reason why no volcanic phenomena arose along this part of the dislocation was because this part was land, and accordingly sea-water was not admitted in quantity to the inner crust of the earth? For this northern portion of Venezuela and the adjacent sea, including Tobago and the northern part of Trinidad, was land all through the Tertiary Era, up to the time of the development of the great Antillean Dislocation; while all the region south and west was sea, as I have on several occasions shown, and especially in my paper on the 'Geological Connexions of the Caribean Region.' I am glad here to use P. Martin Duncan's words, to show that he too had been led to the same conclusion, which is borne out by Karsten's observations on the geology of South America:—

> 'Formerly, when the great plains through which the Orinoco passes were a Miocene sea-bottom, there may have been an open sea, as large as the Caribbean, to the west and south, and the coral-reefs would have been supported by the outliers of the mica-slate ranges of Colombia.' (Q. J. G. S. vol. xxiv, 1868, p. 15.)

And, since I wrote the above-mentioned paper (Trans. Canad. Inst. vol. viii, 1908–1909), I have found the cogency of the reasoning in favour of a communication by sea between the Pacific Ocean and the Caribean region through the Orinoco and Amazon valleys in no way diminished.

---

[1] Q. J. G. S. vol. lviii (1902) pl. x.

[2] See Geol. Mag. dec. iv, vol. vii (1900) p. 324.

[3] See 'Growth of Trinidad,' Trans. Canad. Inst. vol. viii (1904–1905) p. 41. For a further proof, see Proc. Victoria Inst. Trinidad, 1903, p. 529 (p. 512 of original paper).

As additional testimony to the Pacific alliances of the West-Indian Tertiary fauna, I may mention here the fossil surgeon-fish from Antigua (*Zebrasoma deani* Hussakof) described in Bull. Am. Mus. Nat. Hist. N.Y. vol. xxiii, 1907, p. 125. The living forms of the genus are confined to the Indian and Pacific Oceans.

I am sorry that in my paper on the 'Geological Connexions of the Caribean Region' I omitted to notice the extremely pertinent remarks made by the late Dr. W. T. Blanford in the discussion on Dr. Spencer's papers on the West Indies. I owe the possession of the report of this discussion to my friend, Mr. Robert S. Reid, of Tobago. As Dr. Blanford's remarks bear so strongly on the arguments for the Tertiary Atlantis, I trust that I may be allowed to quote them here as supplementary to my above-mentioned paper:—

> 'Omitting bats, the rodents and insectivora of Cuba, Hayti, and Jamaica have quite as strong affinities with African as with American forms. There are no insectivora in South America, and the North American genera are remote from the West Indian, the nearest allies of the latter being found in Madagascar. It is possible that the West Indian mammals entered the country when it was part of a land extending from South America to Africa, and since the immigration of these types, which must have been in the older Tertiary times, there is nothing to show that the West Indies as a whole have been united to either North or South America.' (Q. J. G. S. vol. lviii, 1902, p. 366.)

V. CONSIDERATIONS ON THE GEOLOGY OF TRINIDAD.

Duncan's 'Sketch of the Geology of Trinidad'[1] is so full of inaccuracies that it would occupy too mûch time here to correct it. I will merely pass on to his statement (on p. 12) that the fossiliferous deposit at St. Croix is in the same series as the cliffs at San Fernando. I cannot admit this, nor can I admit that the alliances of the fossils from the limestones of San Fernando are closer with those of the Jamaican Miocene than with those of the chert of Antigua. My acquaintance with the fossils of the chert of Antigua is extremely limited, and I could never have instituted such a comparison. As to the fossils of the *Orbitoides* Bed, the list given by me at p. 572 of vol. xxii (1866) of this Journal shows only a single species common to Jamaica, namely the *Orbitoides*, and that is not Miocene. I leave out the *Natica*, for it was merely a cast; and I am not at all sure about it, though I regarded it as a Miocene species when I wrote that paper.[2] It is true that I gave certain generic names of fossils; but, as I have never found specimens in a condition admitting of specific identification or description, they would form an insufficient basis for such a statement as that made by Duncan, in face of the facts pointing the other way.

I do not feel certain of the exact place that the Manzanilla Beds ought to occupy, as I have failed to find anywhere else a similar

---

[1] Q. J. G. S. vol. xxiv (1868) pp. 10–11.

[2] See also Q. J. G. S. vol. xlviii (1892) p. 536.

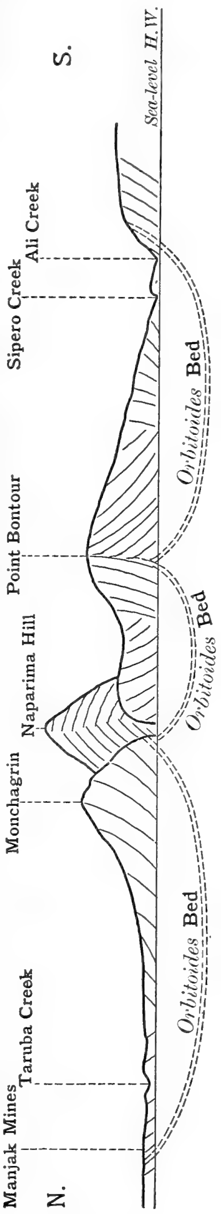


Fig. 4.—*Diagram showing the position of the* Orbitoides *Bed beneath the Naparima Marls, Trinidad.* *(See also Q. J. G. S. vol. xlviii, 1892, p. 522, fig. 1.)*

fauna. But I have assumed them to be older than the Tamana and St. Croix Beds. In any case, I have little doubt of the Miocene age of the latter; while the lowest beds of the Naparima Series, namely the *Orbitoides* Bed and the *Leda* and *Nucula* Beds, are Eocene, and pass down to the Cretaceous. However, in his paper on the 'Older Tertiary Formations of the West Indian Islands'[1] Duncan admits the Eocene age of these beds.

By the kindness of the Directors of the Marbela Manjak Mines (Mr. James Wilson and Mr. Bernstein) and of the Engineer of the mines (Mr. Raspass), I have received samples of the rocks passed through in sinking the shafts and adits of the mines, as well as other information. I published a first note on this in the 'Geological Magazine' for 1904 (dec. v, vol. i, p. 276); but this was extremely imperfect, and the subsequent information which I acquired caused me to publish a second note: this appeared in the Bulletin of the Agricultural Department of Trinidad. A wider publicity would have been desirable, but I was not able to secure it. I sent, however, copies to all persons and institutions that seemed likely to care for them. In this second note I announced the discovery of the *Orbitoides* Bed at a depth of 200 feet, underlying the manjak-bearing strata. I further discussed the characters of the *Orbitoides* and their distribution, and the origin of the manjak. The manjak mines are situated within the area coloured as belonging to the Nariva Series in the map attached to the Geological Report on Trinidad (1860). The strata passed through in sinking the mines represent the equivalents in time of the whole Naparima Series, extending downwards from the Miocene inclusive to the Eocene and top of the Cretaceous. The Nariva Series is not, therefore, a separate formation, but a part of the

---

[1] Q. J. G. S. vol. xxix (1873) p. 549.

Naparima Series, the differences in mineralogical characters being due to depth of water and other conditions. This has been a much-debated question,[1] and I think that it may now be regarded as settled. The true Naparima Marls, including the foraminiferal and radiolarian series, were deposited in deep and comparatively clear water; while the Nariva Series was at the same time formed on the margin of the deep-water area, and subject to invasion by flood-water as well as tide-water. Hence the difference in mineral constitution. The presence of the *Orbitoides* Bed shows that the Eocene formation probably underlies the whole region. It is exposed wherever brought-up by faults or folds, as at Nos. 4, 6, 7, 8, & 15 of the sketch-section from Taruba Creek to the Oropuch Lagoon, vol. xlviii (1892) of this Journal, p. 522. I subjoin a modified copy of that diagram (fig. 4, p.697), showing the probable position of the *Orbitoides* Bed in that section.[2]

When writing the paper to which I have just referred, I was still under the impression that *Orbitoides* and *Nummulina* were found in West Indian Miocene strata, though I had not so found them myself. My later experience led me very strongly to doubt this, and to regard these foraminifera as characteristic of the Eocene and possibly of even earlier formations. I regret that so much confusion has followed upon this mistake, which I believe was primarily due to the correlation of certain West Indian with Maltese rocks considered to be Miocene but now called 'Oligocene.'

A noticeable addition to the fauna of the *Orbitoides* Bed is to be recorded here. It is *Corax pristodontus*, of which I lately found a tooth in the *Orbitoides* Bed. This tooth was determined for me by Dr. A. Smith Woodward, of the British Museum (Natural History), and it will be seen that it adds to the Cretaceous affinities of the *Orbitoides* Bed, already fairly obvious.

The conclusions here stated vary from those set forth by Mr. Jukes-Browne & Prof. Harrison in their paper on Barbados,[3] for I place the line between the Pliocene and the Miocene at the top, and not at the bottom of the Naparima Marls (or Oceanic Series). But, in a note on Prof. Gregory's paper,[4] Mr. Jukes-Browne says:—

> 'We are quite prepared to accept Dr. Gregory's conclusion that the Oceanic Series is of Miocene age, the more so as Dr. Spencer has come to the same conclusion with respect to the Radiolarian Earths of Cuba.'

As this is in practical agreement with my conclusion, I think that it may now be regarded as clear (1) that the Calcareous Formation of Antigua, as also the *Orbitoides* Bed of Trinidad and the Scotland Beds of Barbados, is Eocene (or older), and that all these formations preceded the volcanic era; and (2) that the Oceanic Series of both Trinidad and Barbados are Miocene, and coeval

---

[1] See Geol. Mag. dec. iv, vol. vii (1900) p. 322.

[2] See my account of the Naparima Series (*op. cit.* p. 523), where I have indicated the position of the *Orbitoides* Bed at several points.

[3] Q. J. G. S. vol. xlviii (1892) p. 218.

[4] *Ibid.* vol. li (1895) p. 311. See also G. F. Franks & J. B. Harrison, *ibid.* vol. liv (1898) p. 550.

with the volcanic era. Once these fundamental positions are established, the other formations in the West Indies will easily drop into line. We are assured that the St. Barts formation is Eocene and the Anguilla formation Miocene. It might be inferred likewise that the Oceanic rocks of Cuba, Haiti, and Jamaica are Miocene; but I think that it will be safer to await more certain evidence before making quite sure.

To avoid misconception, I must point out that in using the expression 'Nariva Series' in this paper I refer only to the series so designated north of Naparima Hill and the Naparima Anticline, and not to the South Naparima 'Nariva Series,' about which I am not now in a position to speak so positively.[1] I may simply mention that I have found *Orbitoides* and *Nummulina* near Princestown, and therefore presume that the Eocene beds are developed in that neighbourhood.

Postscript.—I had finished writing this paper before I became acquainted with that of Prof. J. B. Harrison, on 'The Coral-Rocks of Barbados,' contained in vol. lxiii (1907) of this Journal. As the conclusions at which I have arrived, so far as they extend, are in accordance with Prof. Harrison's, I do not think it desirable to alter anything that I have written. I may add, however, that his second conclusion (p. 336) shows that the word 'Oligocene' as used by writers on West Indian geology is not only unnecessary but misleading—inasmuch as it is applied to the Eocene of Barbados, Trinidad, and Antigua, as well as to the Bowden Beds of Jamaica, the Caroni Series of Trinidad, and the Miocene of Haiti and elsewhere.

VI. NOTE ON THE ORIGIN OF MANJAK, PETROLEUM, ETC.

The association of carbonaceous matter with Oceanic beds is not less remarkable in Barbados than in Trinidad. In explanation of that fact, I cannot do better than quote an extract from my second note on the Manjak Mines, premising merely that, as in Trinidad the vegetable materials came from the South American continent, so in Barbados they came from the Atlantis continent; and that the presence of this carbonaceous matter, no less than the conglomerates of Chalky Mount, is evidence of the former existence of that continent:—

> 'The origin of the carbonaceous substances occurring in Trinidad is to be found in the vast quantities of vegetable matter brought down by the rivers from the continent of South America. This matter, being of a slightly greater specific gravity than water, is subject to the laws which govern the removal and deposition of sediment or clastic material. Now, one of these laws is that material of like specific gravity, and of like fineness or coarseness of grain or dimensions of the component parts, is deposited together and apart from dissimilar materials. Hence the vegetable matter brought down by the rivers was deposited in layers, banks, or strata, becoming interstratified with other sedimentary materials as the process of sedimentation and deposition

---

[1] See J. B. Harrison & A. J. Jukes-Browne, 'The Oceanic Deposits of Trinidad' Q. J. G. S. vol. lv (1899) p. 182.

went on. Chemical changes supervened which converted the vegetable tissues into the forms in which we now find them—namely, lignite, asphalt, manjak, and petroleum.'[1]

EXPLANATION OF PLATE L.

Map showing the trend of the great Antillean dislocation, on the approximate scale of 28 miles to the inch or 1 : 1,775,000.

Discussion.

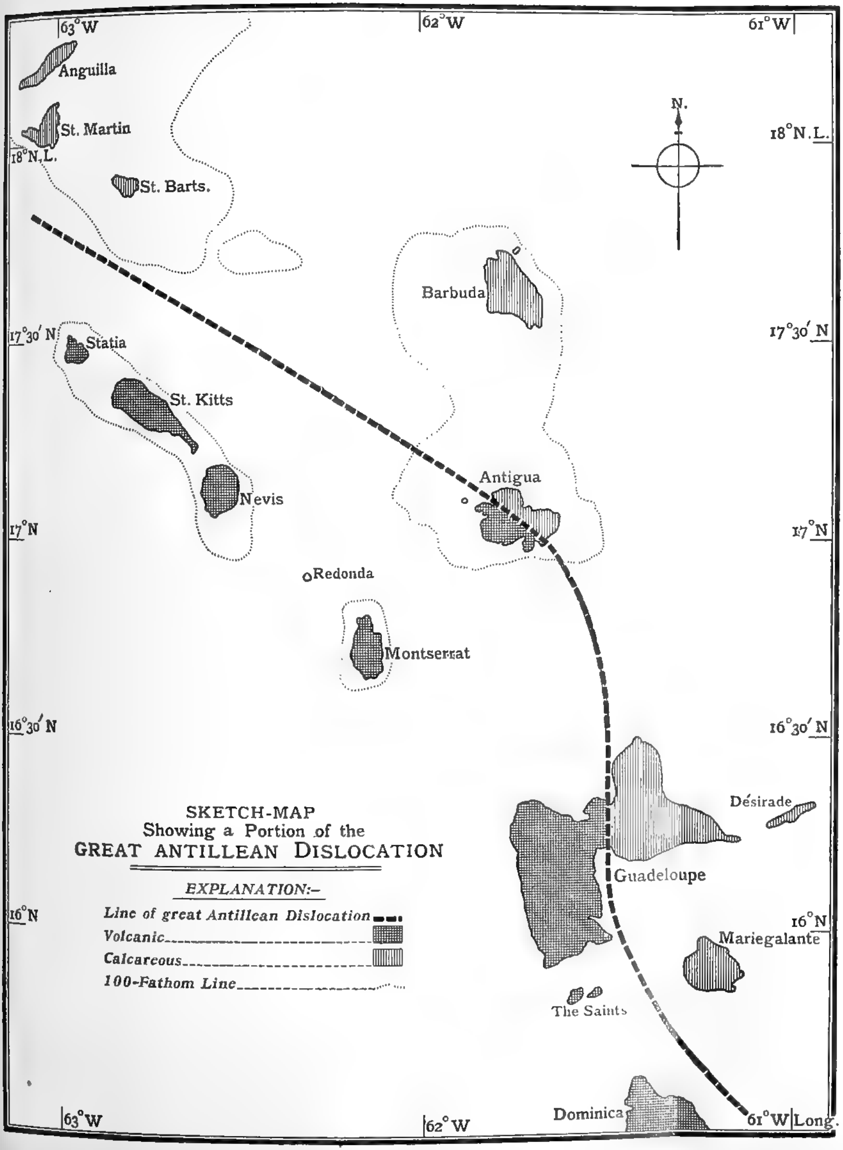
Mr. G. P. Wall, after referring to his long-standing acquaintanceship with the Author, which extended over more than half a century, remarked that the geological conditions in the West Indian islands were highly complicated, and it was difficult to collate or synchronize the formations with those of the well-known European series, or those of other areas. Moreover, it might be that the climate and the environment of the tropics had not varied so much during Tertiary times, and had not, therefore, involved that change or modification in the succession of organisms which was so marked in temperate climes.

In Eastern Venezuela there was a great development of Lower Cretaceous strata, comprising vast beds of indurated limestone rising to altitudes of 7000 feet; the same formation was found in New Granada and the range of the Andes, a fragment being prolonged into Trinidad. This mountainous district was known as the Serranía, while the Llanos consisted of undulating grassy plains dating from Tertiary time. Similar developments of Lower Cretaceous existed in the Jura district, where lofty, highly inclined escarpments of compact limestone rose to great elevations, as at Sonceboz (11 miles from Bienne) and in the Münster Valley.

In Jamaica the Cretaceous was of later age, belonging to the Hippurite stage. The eastern portion of that island was mountainous, rising to 7500 feet, and the fossils were found in a crystalline state; but in the western districts the conditions were simpler: the Clarendon Valley had a floor of slightly arched limestone, crowded with *Caprina* and allied genera. Rising on the flanks of this valley were marls and loose sands full of foraminifera, probably of transition or Eocene date—succeeded by the locally termed 'White Limestone'—a dense rock of great thickness and extension (also developed in the adjacent large island, Santo Domingo) and recognized as belonging to the Miocene Period; finally came the more recent coastal and other beds of coralline and loosely aggregated strata. It would appear, then, that the floor of the Caribbean Sea consisted in part of Lower, in part of Upper Cretaceous rocks, through which igneous eruptions had burst, forming the entire structure of several of the islands—and well shown on the Soufrière of St. Vincent (3000 feet), where alternations of beds of lava, ashes, and scoriæ were inclined in proportion to the elevation, just as in other volcanic masses (as, for example, Etna) which have been built up by eruptive outbursts.

---

[1] See Crosby, 'Native Bitumens & the Pitch Lake of Trinidad' American Naturalist, April 1879.



SKETCH-MAP
Showing a Portion of the
GREAT ANTILLEAN DISLOCATION

20. *The* GEOLOGY *of the* DISTRICTS *of* WORCESTER, ROBERTSON, *and* ASHTON (CAPE COLONY). By R. H. RASTALL, M.A., F.G.S., Fellow and Lecturer of Christ's College, Cambridge. (Read February 22nd, 1911.)

[PLATE LI—GEOLOGICAL MAP.]

CONTENTS.

I. INTRODUCTION AND BIBLIOGRAPHY.

DURING the Long Vacation of 1910 I was enabled to pay a visit to South Africa, partly for the purpose of making collections for the Sedgwick Museum at Cambridge, and partly for original research in South African geology. Acting chiefly on the advice of Dr. A. W. Rogers, the head of the Geological Survey of Cape Colony, I undertook the investigation of the neighbourhood of the towns of Worcester, Robertson, and Ashton, in the Western Province of Cape Colony. Owing to special conditions, the geology of this district comprises some features of exceptional interest, and the elucidation of the problems there presented would cast valuable light on several obscure features of the geological history of the country as a whole. The most important of these problems refers to the origin and age of the Worcester-Swellendam Fault, one of the greatest dislocations of its kind with which we are acquainted. This forms the principal subject of the following paper; but several other questions are dealt with in considerable detail, especially the lithological character and structure of the Malmesbury Series, the oldest rocks of this part of the Colony—a subject on which hitherto little work has been done. Incidental reference is made to other points bearing on the principal objects of the investigation.

The district is comprised in Sheets 1, 2, and 4 of the geological map, on the scale of about $3\frac{3}{4}$ miles to the inch, issued by the Geological Commission of the Cape of Good Hope, and many

references to the geology are scattered through the Annual Reports of the same Commission. The most important publications on the geology of this region are enumerated below.

Bibliography.

BAIN, A. G. 'On the Geology of Southern Africa' Trans. Geol. Soc. ser. 2, vol. vii (1856) pp. 175–92.

BAIN, THOMAS. 'Notes on the Geology of the Western Districts' Cape Monthly Magazine, ser. 2, vol. xv (1877) pp. 171–78.

DUNN, E. J. Geological Sketch-Map of Cape Colony. London, Stanford, 1873.

——. Geological Sketch-Map of South Africa. Melbourne, 1887.

HATCH, F. H., & CORSTORPHINE, G. S. 'The Geology of South Africa' 2nd ed. London, 1909.

ROGERS, A. W. 'Summary of the Work done in the South-Western Districts' 1st Ann. Rep. Geol. Comm. Cape Colony, 1896, pp. 13–14.

ROGERS, A. W., & SCHWARZ, E. H. L. 'Report on Caledon, Bredasdorp, Swellendam, & Southern Part of Worcester' Ann. Rep. Geol. Comm. Cape Colony, 1898, pp. 37–54.

—— ——. 'Notes on the Geology round Worcester supplementary to the Accounts published in the 1st & 2nd Annual Reports' *Ibid.* pp. 83–84.

ROGERS, A. W., & DU TOIT, A. L. 'An Introduction to the Geology of Cape Colony' 2nd ed. London, 1909.

RUBIDGE, R. N. 'On some Points in the Geology of South Africa' Q. J. G. S. vol. xv (1859) pp. 195–98.

SCHWARZ, E. H. L. 'Summary of the Work done in the Tulbagh Area & Worcester District' 1st Ann. Rep. Geol. Comm. Cape Colony, 1896, pp. 27–29.

——. [Quoted in] Report of the Geologist. 2nd Ann. Rep. Geol. Comm. Cape Colony, 1897, pp. 3–38 & pl. ii, sections 1 & 2.

——. 'Summary of Work done during 1897 in the Robertson, Lady Grey, Montagu, & Eastern Parts of the Swellendam District' *Ibid.* App. II, pp. 53–58.

——. 'Geological Survey of the Divisions of Tulbagh, Ceres, & Worcester' 10th Ann. Rep. Geol. Comm. Cape Colony, 1905, pp. 259–90.

II. GENERAL GEOLOGICAL STRUCTURE.

Within the area here dealt with a considerable variety of geological formations is found, ranging from the pre-Cambrian to the Cretaceous, but with notable and important gaps in the succession. There is, in addition, a considerable development of gravels, loams, and alluvium of recent origin. The most important formation, and the one which covers the greatest area in the district, is the Cape System; while in certain parts the strata of the Karroo System also occur to a considerable extent.

The formations now actually seen in the district may conveniently be tabulated as follows:—

Recent gravels and loams.	
Enon Conglomerate, etc.	Lower Cretaceous.
Ecca Shale.	Permo-Carboniferous.
Dwyka Series.	
Witteberg Series.	Devonian and Carboniferous.
Bokkeveld Series.	Lower Devonian.
Table Mountain Series.	Lower Devonian or Silurian.
Malmesbury Series.	Pre-Cambrian.

In the southern part of Cape Colony, the Witteberg Series seems to pass conformably into the Karroo System, though towards the north a marked overlap occurs, so that the Karroo rocks rest unconformably on all the older systems. There is thus evidence of a differential movement, which does not seem to have noticeably affected the rocks of the south-west.

The Dwyka and Ecca rocks of the Worcester district resemble in all essential details those of the Karroo area in the north, and were undoubtedly formed in direct continuity with them; and their present isolated position is a result of post-Karroo disturbance.

Since the composition and characters of the Enon Conglomerate constitute one of the most important subjects treated of in the present paper, the consideration thereof must be deferred.

All the rocks up to and including the Karroo System have in this area undergone important disturbances and dislocations, and even the Enon Conglomerate shows unmistakable evidence of earth-movement of considerable intensity; so it is evident that in recent times the region has been subjected to great disturbance, and the prevalence of hot springs, as at Montagu and Brand Vley, suggests that activity is even now by no means extinct.

III. Physiography of the Area.

The region under investigation is one of very varied topography, presenting many features of interest from the standpoint of the physical geographer, and it illustrates with especial clearness the relation between scenery and geological structure. There is perhaps no part of the world where the scenery is so closely dependent upon the character and arrangement of the underlying rocks as in the western portion of Cape Colony; and here there has been a complete absence of complicating factors, such as glaciation or recent submergence and re-elevation, which have played so important a part in modifying the topography of many northern regions. Hence the effects of a powerful and long-continued process of denudation can be effectively studied.

The area as before defined lies wholly or almost wholly within the drainage-basin of the Breede River, one of the largest streams of Cape Colony. It is bounded on the north by the Hex-River Mountains and the Langebergen, which form one continuous range trending roughly from west-north-west to east-south-east, and only broken through at intervals by some of the larger tributaries of the Breede, such as the Hex River and the Kogmans River, both of which rise to the north of the principal range. These mountains attain an average height of some 5000 feet, the culminating peak, Matroosberg, having an altitude of about 7400 feet. The southern slope of the range is exceedingly steep, and this has a most important bearing on some geological features of comparatively recent origin. In front of this great escarpment comes a narrow strip of foot-hills, varying in width from 1 to 5 miles

and usually ranging from 1000 to 2000 feet in altitude, reaching 3000 feet only in the neighbourhood of Robertson, where a large intrusion of granite forms a conspicuous peak of 3100 feet. Below and in front of these foot-hills stretches the broad valley of the Breede River, which is in parts diversified by hills of considerable height, but sometimes forms a plain as much as 10 miles wide: this is bounded on the south and west by the Zonder Einde Mountains and other ranges. In the north-western part of the district, north of the Hex River, the trend of the principal northern chain undergoes a change, curving round to the north and becoming parallel to the other mountain-chains of the coastal region of Western Cape Colony; whereas the Langebergen beyond Swellendam assume an east-and-west trend, parallel to the other ranges of the south coast. As will be shown later, this change of direction is intimately connected with geological structure, and is of the utmost importance in the study of the tectonics of the district.

The scenery is characteristic and in parts very beautiful, especially in the mountain-ranges, where some of the passes, such as the Hex-River Poort and Kogmans Kloof, show scenes of great magnificence. The contrast is very striking between the rugged and exceedingly steep mountains of Table Mountain Sandstone and the wide alluvial plain of the Breede River at Worcester, which has been carved out of the softer beds of the Bokkeveld, Karroo, and Enon formations. The scenery of the district can be well seen from the railway, since the main line from Cape Town to Kimberley and Johannesburg runs through the Hex-River Pass after leaving Worcester, and the line of the New Cape Central Railway runs along the foot of the Langebergen from Worcester through Robertson and Ashton, towards Swellendam and the south coast. The region is, therefore, easily accessible.

IV. The Worcester District.

The town of Worcester lies on the northern edge of the great alluvial flat of the Breede Valley, some 5 miles south-west of the mouth of the Hex-River Pass, which is now the principal line of railway-communication between Cape Town and the Orange Free State and the Transvaal. It forms, therefore, a convenient centre and starting-point for the investigation of the district. The outcrop of the Malmesbury Series is here unusually wide, extending over a total distance of some 6 miles; consequently this is a specially favourable locality for studying the general character of the Series. The Malmesbury rocks here vary considerably in lithological character, but the general conformation of the ground is very uniform throughout. They form an expanse of comparatively low, rounded, rolling hills, varying in height from about 1000 to 1500 feet, diversified occasionally by small crags—or kranzes, in the local idiom. Along the river-courses there is usually a good deal of recent alluvium, and in some parts exposures are rather deficient. The junction between the Malmesbury Series and the

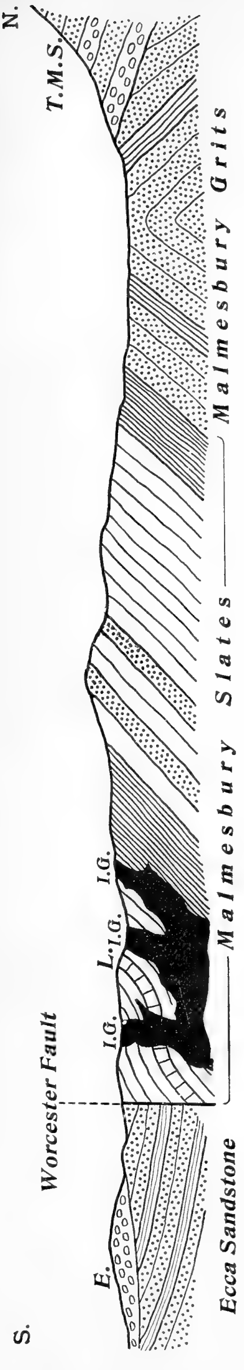
overlying Table Mountain Sandstone is well seen in the deep kloof at the head of the Hartebeest River, sometimes called the Fairy Glen, in which the new waterworks for the town of Worcester are now being constructed.

The general strike of the Malmesbury Series is fairly uniform, being on the average about west 10° north and east 10° south. In a few localities, and especially just to the north of Worcester, there are small areas of local disturbance, due to special causes, such as igneous intrusions and dislocations; but these are not of much importance. Only one extensive rock-mass, in Brewels Kloof, appears to be of igneous origin: this will be separately dealt with hereafter. Immediately north of Worcester are some small patches which appear to be highly metamorphosed granitic dykes: all the rest of the area is occupied by rocks of undoubtedly sedimentary origin, which have undergone a considerable amount of dynamic metamorphism.

The field-relations and general characters of the Malmesbury Series can be best illustrated by a somewhat detailed account of a section running north and south, from the town of Worcester to the base of the Cape System in the Fairy Glen, a distance of about 7 miles. The relations here disclosed are illustrated in fig. 1.

As before stated, the town itself stands on the alluvium of the Breede River, which here forms a flat plain some 4 miles wide. However, immediately north of the town the ground begins to rise, and in the goods-yard at the railway-station there is a very fine exposure showing Enon Conglomerate resting upon Ecca Sandstone that yields plant-remains. The conglomerate is again well exposed at the dam of the small reservoir about a mile north-west of the church; and, owing to recent

Fig. 1.—*Diagrammatic section from Worcester to the foot of the Hex-River Mountains. (Total length = about 7 miles.)*



[E. = Enon Conglomerate. L. = Limestone-band in the Malmesbury Slates. I.G. = Intrusive granite. T.M.S. = Table Mountain Sandstone.]

excavations, very good unweathered specimens can here be obtained. This conglomerate forms a low rounded hill, to the north of which is a level expanse of loam and brick-earth, about half a mile wide. In this loam are a good many gullies (sluits) formed by streams during heavy rains, and, at the bottom of some of these, exposures of Ecca Sandstone can be seen. At the foot of the next slope is an outcrop of a peculiar shattered quartzose rock, which is believed to indicate the position of the great fault.

Immediately to the north of this are several small quarries in which a variety of rock-types are to be seen, including a band of white crystalline marble associated with highly-crushed granitic dykes. This marble probably represents a band of limestone, which has been metamorphosed by the granitic intrusions, as well as crushed by earth-movements, and it is associated with some greasy-looking schistose rocks of remarkable character. For some distance north of this there are numerous bands of a hard rock, which is called by Dr. Rogers 'phyllite-gneiss.' As we shall see presently, these are undoubtedly igneous intrusions that have undergone foliation by earth-movement.

For some 3 miles northwards the ground is occupied by a monotonous series of silvery, greenish or grey, fine-grained, schistose rocks, which may be called slate, phyllite, or schist; here and there only are to be seen thin bands of grit or quartzite, which seem to be usually quite impersistent, and of little importance. A somewhat thicker band of grey quartzite occurs near a sheepfold, on a kopje about 3 miles north of the railway-station. The phyllite or slate weathers into soft, brownish-grey, sandy flags, which cover a great stretch of country: exposures are frequent, but of little interest.

Following the cart-track from this point over the low watershed to the first tributary of the Hartebeest River, we note that exposures become scarce, and a great spread of gravel and sand is encountered, which continues for some distance. The deficiencies of this part of the section must be filled in from parallel traverses, made both to the east and to the west of this line.

When next exposed, higher up the Hartebeest River, the Malmesbury rocks are represented by massive green and purple grits of a kind not before seen: the unusual colours are probably due to the fact that the specimens here obtained are unweathered, coming from the excavations for the pipe-line of the waterworks. They appear to be similar in all essential characters to the grey and brownish grits of the Hex-River Pass, on the east. These grits can be seen to disappear under the Table Mountain Sandstone; the latter has a fairly steep dip to the north, and here forms an escarpment some 4000 feet high, cut up into prominent peaks and ridges. Where last seen, the Malmesbury Grits also exhibit a strong dip to the north, at a much steeper angle than the Table Mountain Sandstone.

Throughout the whole of the distance from the Worcester Fault

almost to the foot of the mountains, a distance of about 6 miles, the dip of the Malmesbury Beds is uniformly to the south, and nearly always at a steep angle, often exceeding 50°. It is only at the extreme north of the exposure, as just mentioned, that the dip is northerly. It follows that, if there be no repetition by faulting or isoclinal folding, the total thickness must be enormous. Unfortunately, the data at our command are insufficient to decide this question. It must be stated however, that, so far as my own observations went, I could see no evidence of repetition; and the distinct difference of lithological character at the northern as compared with the southern extremity of the section is, on the whole, evidence bearing against this supposition.

Another specially favourable opportunity of examining a large part of the Malmesbury Series is afforded by the road, which passes along the right bank of the Hex River from De Wet Station in a northerly direction. Some 3 miles above the station the base of the Table Mountain Sandstone is reached, and in this distance exposures of the older rocks are frequent. The road from Worcester winds round the southern side of a low but steep hill, known as Meirings Berg; and the numerous cuttings here are excavated in a soft silvery slate, with highly developed cleavage and a generally sericitic appearance. This may perhaps be described, for convenience, as silvery phyllite. Passing northwards, a more gritty facies soon sets in; and, from a point a short distance south of De Wet Station to the base of the Table Mountain Sandstone, the whole may be classified as grit, with occasional quartzite-bands. The coarser types approximate very closely to the grits at the head of the Hartebeest River; and the direction of strike is quite in agreement with the view that these are continuous. On these grounds I have divided the Malmesbury Beds into two series, as shown in the accompanying map (Pl. LI)—a series mostly composed of grits, lying to the north, and presumably the older; and a broad belt of slates and phyllites on the south, which appear to be newer in stratigraphical sequence, and are cut off abruptly by the Worcester Fault, their actual thickness being hence quite unknown.

An interesting and important observation was made on the main road, on the other side of the Hex River. Near to the house marked on the Survey map as Maze Kraal, there was found a small exposure of a highly decomposed rock, full of small crystals of ottrelite. It seems highly probable, in fact almost certain, that this is the westerly continuation of the narrow band of ottrelite-schist at Waai Kloof, near Nuy, which lies some miles to the east, but exactly in the required direction, assuming the strike to remain uniform, as it actually appears to do. This rock was only seen at one point in the Hex-River Pass, but its assumed position is indicated on the map (Pl. LI).

V. THE PETROGRAPHY OF THE MALMESBURY ROCKS OF THE WORCESTER DISTRICT.

As we have already seen, the Malmesbury rocks of the Worcester district can be divided on general grounds into two series, which differ somewhat markedly in lithological character. The lower division is best seen in the fine road-section along the right bank of the Hex River, north of De Wet Station, while the upper series is well displayed in the numerous kopjes which form the rolling ground extending for some miles due north of Worcester. The massive grits at the base of the whole are also now well exposed, in the excavations for the new waterworks at the head of the Hartebeest River. A short distance north of Worcester bands of limestone and masses of intrusive igneous rock occur in the upper series; while the igneous rocks of Brewels Kloof form an exceptional type, and need separate treatment.

(1) The Sedimentary Rocks.

(*a*) Lower division: the gritty series.—The rocks forming this series are on the whole very uniform in character, the chief variations being in the matter of colour, which is obviously of subsidiary importance. They may be collectively described as grey, green, or purple grits, usually massive and rather fine in texture [9463].[1] When weathered, they often take on a brownish colour; and here and there comparatively thin bands of white or very pale grey quartzite are met with, as for example near the farmhouse Zeekoe Gat. Passing southwards, these grits and quartzites gradually give place to a great thickness of flags and gritty slates, usually dark grey. These are very different from the silvery slates and phyllites of the upper division, which begin about half a mile south of De Wet Station.

A typical specimen of one of the grits from a short distance north of De Wet [9459], when examined microscopically, is seen to consist for the most part of angular and subangular grains of quartz, with abundant small flakes of a yellowish mica and occasional grains of tourmaline, zircon, epidote, etc., which are clearly of detrital origin. In some specimens, but not universally, grains of felspar occur in small quantity. The grains are somewhat sparsely distributed in the cementing material, which is relatively abundant. The cement is very fine in texture, so that its constituents are somewhat difficult to determine. It appears to be chiefly composed of quartz and mica in minute grains and flakes, but a good deal of some irresolvable argillaceous material also seems to be present.

It is noticeable that all the larger quartz-grains show a certain amount of corrosion at the edges, as if some kind of reaction had taken place between the quartz-grains and the constituents of the cement. This undoubtedly indicates incipient metamorphism, but whether this is thermal or dynamic in character, it is impossible to say with certainty.

---

[1] The numerals in brackets refer to slides in the Sedgwick Museum collection, Cambridge.

(*b*) Upper division: the slaty series.—The rocks of this series are notably finer in texture than those just described, and appear to have been deposited in deeper water; but they are on the whole of very similar character, and the transition from the gritty to the shaly type is gradual. The lower part of this series is well seen along the Hex-River road, on the farm Meirings Berg, and also in the neighbourhood of Brewels Kloof; while the upper part is excellently exposed on the low hills immediately north of the town of Worcester.

In this division, the dominant lithological type is a fine-textured silvery-grey or olive-green rock, which has been variously described as slate, schist, and phyllite. Cleavage and schistosity are conspicuous, while strain-slip cleavage, both microscopic and on a large scale, is very common. When weathered, these rocks take on a greenish-yellow or brownish tinge, and shatter very readily under the influence of weathering agents.

A microscopic examination of specimens of these rocks reveals a structure and mineralogical composition very like that previously described in the more gritty division, but of course on a smaller scale. In most of the specimens from this division felspar is fairly abundant in small rounded grains, and it is sometimes discernible also in the fine cement. The principal coloured mineral is olive-brown biotite, which is sometimes converted into chlorite. In these specimens also the quartz-grains show incipient metamorphism, indicated by reaction with the ground-mass. Certain beds have some resemblance to volcanic ashes, owing to the presence of broken crystals of felspar and much micaceous material.

In a deep sluit to the west of the flag-quarry, and north-west of the marble-quarry, there is a small exposure of conglomerate in the Malmesbury Series. This rock is highly schistose in character, with augen-struktur, and consists of scattered pebbles embedded in a well-foliated silvery phyllite, which is a good deal weathered and stained by iron-oxide. The pebbles, which are not relatively abundant, vary from half an inch to 5 inches in diameter, but the larger ones are rare; they are for the most part oval in form, and evidently waterworn. They consist of vein-quartz and quartzite, and do not exhibit any special characteristics. They are chiefly of interest as showing the former existence of sedimentary rocks older than the Malmesbury Series.

(*c*) The calcareous rocks.—The limestone-bands found in the quarry north of Worcester show a great deal of variation, apparently due to different degrees of metamorphism, depending on their proximity or otherwise to the invading tongues of granite. The rocks are here much disturbed, and the relations of the different types of limestone are difficult to make out. In one part of the quarry there is a considerable mass of white crystalline marble, and on the other side are some remarkably contorted bands of a black limestone which does not seem to be much altered: this is only a few inches thick.

The marble is a white or greenish-white rock of fine texture, and very uniform in character. In a slice [9460] it is seen to consist entirely of carbonates, with no other recognizable minerals. A sample was subjected to qualitative chemical tests, and showed no trace of either magnesia or iron, and no matter insoluble in hydrochloric acid; it must, therefore, consist wholly of calcium carbonate, and is consequently a rock of remarkable purity.

A specimen of the black limestone from the other side of the quarry was also examined in the same way: it was found to be wholly soluble in hydrochloric acid. When the solution was neutralized with ammonia, a very small precipitate came down, which probably contains both iron and alumina. A trace only of magnesia was also found. The iron, alumina, and magnesia were all too small in amount for quantitative determination, and the rock is practically pure calcium carbonate: therefore the chemical composition is not inconsistent with the view that this limestone-band is the same bed as the white marble, but less metamorphosed.

(2) The Granitic Intrusions.

About a mile north of Worcester are to be seen over a considerable area frequent outcrops of a rock which has been commonly referred to as 'phyllite-gneiss.' This is a massive strongly-foliated rock of a grey colour, nearly always distinctly lenticular, and often showing sericitic mica on broken surfaces. It is quite apparent, both from a petrographical examination and from field-relations, that this 'phyllite-gneiss' represents masses of granite or granite-porphyry which have been intruded into the sediments at some period prior to the final foliation. The intrusive character is not easy to determine with certainty, but I was lucky enough to find on the ground conclusive evidence on this point. Immediately west of the small hill at the foot of which the marble-quarry is situated are several deep sluits, which have removed the sand and loam down to the surface of the solid rock. In one of these sluits, which is about 6 feet wide and 4 feet deep, there can be seen a contact of the phyllite-gneiss and the slate. From this it is clear that the granite was intruded after the major joints of the sedimentary deposit had come into existence, since the transgression is controlled by these; but both sediment and intrusion alike were affected by the latest and most powerful pressure, which produced parallel foliation in both.

When examined with the microscope [9461–62], specimens of this rock show much less alteration than might be expected from its macroscopic appearance. It is distinctly porphyritic, with phenocrysts of quartz, orthoclase, and oligoclase in a fairly fine-textured ground-mass of granulitic type, consisting of quartz and felspar. Some patches of a dark-green chloritic mineral probably represent original biotite. This rock is a granite-porphyry or quartz-porphyry, of fairly acid composition and alkaline affinities.

A series of specimens of this rock collected from different points

shows a regular gradation of characters, from an almost uncrushed quartz-porphyry as above described to a highly schistose rock, consisting for the most part of finely granular quartz and felspar and sericitic mica, in which the original phenocrysts are represented by much-flattened augen of recrystallized quartz and felspar. The sericitic mica, which is pale brown or colourless, forms very conspicuous streaks curving round the augen.

There is hardly sufficient evidence available to decide with certainty what the form of these intrusions may be, but it seems safe to conclude that they are for the most part of dyke-like habit. At the marble-quarry there is evidence of a considerable degree of disturbance of the strata and also of strong thermal metamorphism; in all probability these granite dykes are offshoots of a larger and more deep-seated mass which is not exposed at the surface: the form of the intrusion, as indicated in fig. 1 (p. 705), is not to be taken too literally, as it is merely diagrammatic and to a certain extent hypothetical.

(3) The Igneous Rocks of Brewels Kloof.

The exact size and boundaries of this mass are somewhat difficult to determine, owing to the roughness of the ground and the poorness of the exposures in some parts, but it appears to be somewhat elliptical in form, and about three-quarters of a mile long by half a mile broad. Where the contact of the igneous and sedimentary rocks can be seen, the former appears to be always inclined at a high angle, sometimes nearly vertical, and the outer portions of the mass show a good deal of shearing. For this reason, it is difficult to determine whether there is any difference of texture between the outer and the inner portions of the mass.

A typical specimen of this rock, when unweathered, is dark blue or grey in colour, heavy and compact, with a spotted appearance, which, as can be seen from microscope-sections, is partly due to porphyritic felspars, and partly to vesicles filled with secondary minerals. When weathered, these secondary minerals offer less resistance than the rest, so that the exposed surfaces frequently show a very conspicuous vesicular pitting.

Thin slices of this rock [9464–65] reveal abundant phenocrysts of plagioclase-felspar and pseudomorphs after some ferromagnesian mineral, together with rounded or oval vesicles, in a groundmass which varies considerably in character owing to different degrees of decomposition.

In some specimens the felspar-phenocrysts are quite fresh, and show extinction-angles corresponding to andesine and labradorite. In other cases the felspar has become more or less turbid, owing to conversion into an aggregate of minute crystals of mica and zoisite. This gives a false appearance of strong refringency, and causes the crystals to present a curious similarity to andalusite.

The ferromagnesian mineral is now represented by chloritic

pseudomorphs, and it was not found possible to determine its original character with certainty. In some specimens it seems to have been biotite, while in others the form of the pseudomorphs is rather more suggestive of augite or hornblende.

The ground-mass varies a good deal in different specimens: in the freshest of all it consists of minute lath-shaped crystals of felspar, with grains of magnetite and flakes of chlorite and biotite. One variety shows a considerable amount of quartz with the felspar. In some specimens the structure of the ground-mass is distinctly andesitic, with well-marked flow-structure indicated by the arrangement of the felspars; while in the quartz-bearing variety the ground-mass is very like that of the porphyrites, for instance, of Canisp or the Cheviot Hills. In the more altered varieties, on the other hand, the minerals of the ground-mass have been converted into an aggregate of carbonates and micaceous substances, with iron ores.

The vesicles contain a considerable variety of minerals, of which the most important are pale-brown mica, chlorite, and epidote, generally with some quartz, and occasionally tourmaline.

With regard to the petrographical character and classification of this rock, it is difficult to make any definite statement. Owing to the high degree of alteration, as shown by the abundance of carbonates, epidote, and chlorite, it is quite evident that chemical analysis would be not only useless, but misleading. Judging from the characters of such minerals as are still determinable, the rock appears to have been originally either a lava or an intrusion of intermediate composition. Some specimens might be described as typically andesitic in character, and the vesicular structure which is so notable and conspicuous affords strong presumptive evidence in favour of extrusion, or at any rate of intrusion under a somewhat thin covering of rock. On the other hand the form of the mass is difficult to reconcile with the supposition of a lava-flow, and is much more strongly suggestive of an intrusion. Owing to the high grade of the subsequent dynamic metamorphism, it is impossible to determine whether or not the surrounding sediments have undergone any contact-metamorphism. The question must therefore be left an open one, and the rock may be provisionally described as porphyrite or andesite.

VI. The Ottrelite-Rocks of Waai Kloof.

When they are followed towards the east, the general character of the Malmesbury rocks is seen to remain very uniform: although, owing to the narrowing of the outcrop, the lower grits become less conspicuous.

About 12 miles east of Worcester, the Coos River cuts through the mountains in a narrow gorge called Waai Kloof, and near the mouth of this gorge is an exposure of a very interesting rock. The prevailing rock of this district is a highly crushed and slickensided grit of uniform character, and presenting few points of interest; but in a small cultivated field, forming an expansion of

the gorge near its mouth, and close to the base of the Table Mountain Sandstone, there is a narrow band of different character. This is considerably harder than the rest, and forms a conspicuous ridge in the middle of the field. This ridge is about 30 yards long and perhaps 15 feet high, and is composed of thick slabs of rock with their bedding (or schistosity) dipping steeply southwards. This rock weathers in a peculiar manner, forming smooth rounded surfaces with a high polish, and is locally known as the Olifants Klip, or Elephant Rock. The same rock can also be traced on the other side of the Coos River, just below the Table Mountain Sandstone, and at this point it is highly disturbed. As before mentioned (p. 707), what appears to be a much decomposed representative of this band is to be seen in the Hex-River Pass; and this observation is of much importance, since, if this really is the same band, an important clue is afforded as to the relationship of the rocks of the Malmesbury Series at these two widely separated points. According to this, the ottrelite-rock probably forms a member of the lower division of the Malmesbury Series, and it appears to lie to the north of the axis of the principal anticlinal fold, as indicated in the section (fig. 1, p. 705).

A small number of specimens of the prevalent rock of this district were collected, and they were found to be for the most part somewhat crushed and slickensided grits of moderate to fine texture, consisting of angular and subangular fragments of quartz, in a rather schistose ground-mass of white mica and minute grains of quartz. The edges of the larger quartz-grains are usually more or less corroded, and in some specimens the characteristic sutural structure of a quartzite can be discerned. There is here evidence of a high grade of dynamic metamorphism. These rocks do not differ in any essential character from the grits in the Hex-River section.

A considerable number of slices was cut from the rocks of Olifants Klip, but all of them showed very similar characters, and they may all be included in one general description [9466–67].

The principal minerals of this rock are quartz, white mica, and ottrelite. In most specimens the rock may be described as composed of more or less rounded grains of quartz of obviously clastic origin, sometimes compound grains or minute fragments of quartzite; along the planes of schistosity lie in great abundance flakes of white mica, somewhat fibrous in character and often curved and contorted. In some cases there is a development of strain-slip cleavage. Scattered through this ground-mass, with a distinct tendency to aggregate in certain bands, are a large number of crystals of ottrelite, measuring up to 1 millimetre in diameter. They usually are roughly hexagonal or rounded plates, thin in proportion to their diameter, so that sections normal to the basal plane show a prismatic form. The edges of the crystals are very irregular, and consequently prismatic sections never show any termination, but are rather fringed at the ends.

The colour of the crystals is to the naked eye very dark blue or

black, and in thin sections a greenish-blue or bluish-grey. The pleochroism is fairly strong, considering the paleness of the colour: the usual tints being greenish-blue for rays vibrating nearly parallel to c 001, and very pale grey or colourless for rays vibrating normal to this. The crystals are optically positive, and the absorption scheme may be expressed as follows: $\mathfrak{a}=\mathfrak{b}>\mathfrak{c}$. The extinction is oblique, $c \wedge z =$ about 9°. A peculiar form of twinning is conspicuous, so that the usual prismatic sections appear to be divided into four portions, of which opposite diagonal pairs extinguish simultaneously. The refractive index is fairly high and the birefringence rather weak. All these characters agree with those of ottrelite.

This rock may be defined in general terms as an ottrelite-schist; and it is highly probable that, in this case at any rate, ottrelite is a product of dynamic metamorphism, since there is no evidence of any contact-action in this neighbourhood. The rock shows a strong resemblance to the typical rocks of Ottré in the Ardennes.

VII. The Robertson District.

In general structure this district closely resembles the neighbourhood of Worcester, but here a slight element of variety is introduced by the occurrence of a large mass of granite in the Malmesbury Series. This mass of granite forms a group of hills, of which the highest rises to an elevation of just over 3000 feet, a height considerably greater than that attained by the sedimentary rocks of that series. As we shall see later, the presence of this mass of hard rock has produced a considerable deviation in the general direction of the Worcester-Swellendam Fault, and this gives rise to a question of great interest: namely, what is the exact nature of the relations between the dislocation and the granite mass?

In this district, just as near Worcester, we can divide the country topographically into three regions: (1) the great escarpment of the Table Mountain Sandstone, here rising to nearly 6000 feet, and forming the range of the Langebergen; (2) the narrow strip of Malmesbury rocks forming foot-hills to the mountain-range; (3) the region south of the great fault, which here forms a district of somewhat more varied topography than farther west. It comprises a hilly region about Roode Berg and Gorees Hoogte, composed of highly folded beds of the Cape System; another hilly region to the west of this, extending from Lang Vley to Nuy, mostly composed of Dwyka Conglomerate and Ecca Shales; and a level or gently undulating district east and south-east of Robertson, which seems to consist for the most part of Enon Conglomerate.

The highly-folded Cape rocks on this side of the fault present some remarkable features: they are bent into a series of rather steep anticlines and synclines, but the most striking feature is that the axes of these folds are almost exactly at right angles to the direction of the great fault, which is parallel to the strike of the Cape rocks in the Langebergen. From the point of view of the physio-

grapher, another interesting feature is that, broadly speaking, the anticlines form hills and the synclines valleys, contrary to what is usual in folded regions. The Breede River cuts through an anticlinal hill about 4 miles west of Robertson, and in the gorge thus produced some magnificent examples of folding on a large scale may be observed both from the road and from the railway. In general terms, it may be said that throughout this district the most elevated ground consists of Table Mountain Sandstone and Witteberg Quartzites, whereas the Bokkeveld Beds, being softer, form low ground, and are often completely hidden by alluvium.

(1) The Malmesbury Rocks.

The rocks composing the Malmesbury Series in the district near Robertson are very similar in general character to those of Worcester; hence it is hardly necessary to describe their lithological character in detail. They consist of a fairly uniform series of rather fine grits and slates of a grey, greenish, or silvery colour when fresh; but, when much weathered, as is commonly the case, the prevailing tint is a pale olive-brown. A bed of dolomite is seen at Keur Kloof, about a mile north of Robertson, and another outcrop of what is (in all probability) the same bed occurs in the road which runs up the valley of the Hoops River, about 3 miles to the east.

The outcrop of the Malmesbury rocks is here rather narrow, averaging not more than a mile in width, except in the neighbourhood of the granite mass, where it expands greatly, as seen on the map. There are not sufficient data available to show to which division of the series, as defined at Worcester, they should be assigned.

In the neighbourhood of the granitic intrusion of Wolve Kloof the Malmesbury rocks are highly disturbed, but there is little or no evidence of thermal metamorphism, although the actual contact of the granite and sediments is exposed in several places. Along the footpath which runs from Robertson to Wolve Kloof, near the ruined water-mill at the entrance to the Kloof, there is a rapid alternation of granite and apparently unaltered sediment, each of which occurs along the path in patches a few yards wide. The junction is evidently very irregular, with tongues of granite projecting into the slates. The latter are much sheared, but no development of contact-minerals can be seen. A short distance north-east of this point, at the top of the first cultivated field on the side of the hill, is an exposure of rock of the phyllite-gneiss type, evidently a crushed granite-dyke.

The succession of the Malmesbury rocks is seen most completely along the road which leads up the valley of the Hoops River. From Robertson as far as the river this road runs over Witteberg Slates and Enon Conglomerate, both of which are well exposed in several cuttings. Near the drift over the river, about 2 miles east of Robertson, there are not many exposures; but a few yards beyond the drift there is by the roadside a patch of typical Malmesbury

Slate, with a dip totally different from that of the Witteberg Beds. Hence it is certain that the main fault must cross the river very near the drift. At this point the road turns northwards and runs parallel with the river for some miles, over a monotonous series of grey sandy flags and mudstones, with occasional bands of silvery slate and soft olive-green shale. The strike of these rocks is about west 10° south, and east 10° north, and the dip is always southwards at an angle varying from 20° to 50°. About half a mile north of the drift is the band of dolomite previously mentioned (p. 715), and close to it is a rather coarse grit, as also a very peculiar schistose rock containing large blocks of black vein-quartz, which impart to it a sort of augen structure. This appears to be a crushed conglomerate, since the blocks of quartz are certainly of detrital origin. This may be compared with the conglomeratic band seen close to the marble-quarry at Worcester, and it is just possible that they are the same, since in each case the conglomerates occur in conjunction with a calcareous band.

Throughout this series cleavage and jointing are very conspicuous in the finer beds, while the gritty beds show these structures less perfectly. Vein-quartz is abundant almost everywhere, and always shows a peculiar blue-black colour. The quartz-veins were evidently injected before the final foliation of the Malmesbury rocks.

Calcareous beds occur in several localities in the neighbourhood of Robertson. The most important of these are on the farm Dassies Hoek, where they are associated with black graphitic shales.[1] Beds of dolomitic limestone are also seen on the Hoops-River Road, and in Keur Kloof, north of the town; the latter occurrence was at one time worked for lime-burning. It is a dark bluish-grey rock, which weathers in a peculiar manner, becoming covered with a thick, pulverulent, white crust. A rough quantitative analysis of this rock showed the presence of 10 per cent. of matter insoluble in hydrochloric acid, 6 per cent. of ferrous carbonate, and 37 per cent. of magnesium carbonate, so that it is correctly described as an impure gritty dolomite.

(2) The Granitic Intrusion of Wolve Kloof.

This large mass of granite has a roughly oval form, and measures, as at present exposed, about 4½ miles from north to south and 2½ miles from east to west. It forms conspicuously high ground, and its central portion rises to a height of over 3100 feet above the sea. The exact outline is difficult to determine, owing to the rugged nature of the ground and a thick covering of vegetation on the lower slopes. By far the best section is seen in Wolve Kloof, a deep and narrow gorge formed by the Nels River, which cuts through the granite for a distance of about 1½ miles. The precipitous sides of this gorge are formed of smooth rounded surfaces of granite,

---

[1] A. W. Rogers & A. L. Du Toit, 'Geology of Cape Colony' 2nd ed. (1909) p. 24.

presumably curved joints, but presenting a strong deceptive resemblance to the curved 'boiler-plate slabs' so characteristic of igneous rocks in glaciated regions. The rock is much weathered, and it is somewhat difficult to obtain really fresh material.

Sections were cut from specimens collected from different parts of the mass, but all are very similar, the chief difference consisting in the presence or absence of phenocrysts of felspar, which are never very abundant and sometimes wanting. Another difference lies in the amount of foliation: the central portion, especially in Wolve Kloof, is free from foliation, whereas near the margin a gneissose structure is often conspicuous. In certain parts aplitic veins are fairly abundant, but otherwise the rock shows little variation.

The granite is a rock of moderately coarse grain, of a prevailing bluish-grey colour when fresh, with scattered phenocrysts of white felspar measuring up to 1 inch in length. The principal minerals are quartz, felspar, and mica, with accessory iron-ores and sphene. The quartz, which was the last mineral to crystallize, forms large irregular crystals, much cracked and shattered, and exhibiting conspicuous strain-shadows. Several varieties of alkali-felspar can be recognized, including orthoclase, microcline, microcline-perthite, and microperthite. These are usually quite clear and fresh, whereas the plagioclase, which occurs in subordinate amount, is distinctly turbid, and for the most part converted into an aggregate of white mica and zoisite. The plagioclase shows very small extinction-angles, corresponding to oligoclase. The soda-molecule of the plagioclase has evidently given rise to soda-mica, while the lime-molecule has formed zoisite. The principal coloured mineral is an olive-brown biotite, which is usually much chloritized and then green in colour. It is full of inclusions, some of which are epidote, while others consist of black opaque iron-ore surrounded by a ring of sphene. This latter fact suggests that the iron-ore may be ilmenite, which has given rise to sphene as a reaction-product. A few large original sphenes are also present. Some of the bigger flakes of muscovite which occur in places may possibly be of primary origin, but the greater part of this mineral is undoubtedly derived from plagioclase-felspar. Some specimens of the granite, especially the more porphyritic examples, show a strong tendency to micrographic intergrowths of the quartz and felspars of the ground-mass [9470-71].

The aplite forms narrow veins and strings penetrating the granite in all directions, but its distribution is somewhat restricted. It consists of quartz and a great variety of felspars, all of alkaline composition, with only the merest trace of biotite. Sphene and small garnets are occasionally present. In this rock the quartz has commonly crystallized before the felspar. No notable difference of composition can be detected between the normal granite and the aplite; the variation is chiefly a matter of texture, though the aplite appears to be of somewhat more acid character [9468-69].

Since the inner parts of the granite mass, where cut through by the Nels River in Wolve Kloof, show no foliation, while the outer portions are much crushed and shattered, it is clear that the

intrusion took place before the final foliation, and that the great size of the main mass protected the interior from crushing, while the margin and the peripheral dykes were strongly foliated. Thus, even at this early stage, before the deposition of the Cape rocks, this intrusion acted as a horst, and that fact has some bearing on the problem of the later faulting.

VIII. The Cape and Karroo Rocks of Worcester and Robertson.

For the purposes of the present paper, it is unnecessary to enter into a lithological description of the rocks of these two series. They are quite normal in character, and call for no special remark. Perhaps the most noteworthy feature is the entire absence of any exposure of the Bokkeveld Series in the neighbourhood of Worcester, on the north side of the Breede River. Since typical Witteberg shales and quartzites are seen in the banks of the river south of Goudini Road Station, and also for some distance in the neighbourhood of Brand Vley, and these beds dip north, it is possible that the whole of this great alluvial flat is really underlain by Witteberg and Karroo beds, although it is frequently assumed that such large valleys are excavated out of Bokkeveld beds, which, as a matter of fact, is generally the case.

Somewhat farther south, over a great area stretching from Brand Vley and the Hoeks River on the west to some miles east of Lang-Vley Station, the ground is occupied by a great development of Karroo rocks, with a strip of Enon Conglomerate on the north. The rocks of the Karroo Series are here quite normal, and just like those of the main area of the Karroo itself. The Dwyka Conglomerate is very thick, but the boulders are mostly small. Good specimens of the whole series can be obtained near Lang-Vley Station; and close to the station in the Ecca Shale is a bed of anthracite, which is now being worked under the name of graphite.

The sandstones of the Ecca Series are exposed at several points near Worcester. In the goods-yard at the station is a very fine exposure showing Enon Conglomerate resting on Ecca Sandstone; and the same sandstone can be seen in many places, in the floors of the sluits formed by heavy rains in the brick-earth flat north of the station. About 3 miles west of Worcester Station is a curious small conical hill, by the side of the railway, which has been quarried, and this also consists wholly of Ecca Sandstone. Here the rock strikes north-north-west and south-south-east, and the dip is about 20° to the east. In all these exposures the dip of the sandstone is either more or less parallel to the fault or towards it, which is of course unusual on the downthrow side. The rock is everywhere very uniform, and consists of a fine-grained greenish or yellowish sandstone with obscure plant-remains, among which sufficient forms have been recognized to establish the age of the formation, at any rate in a general way, as Ecca Sandstone. This sandstone probably underlies a good deal of the alluvial flat of the Breede Valley south of Worcester.

Small isolated patches of Dwyka and Ecca rocks are also seen close to the town of Robertson, and especially along the railway and in the low hills immediately north of it. There is a good exposure of typical Dwyka Conglomerate near the water-mill to the north-west of the town, at the mouth of Wolve Kloof. These rocks are normal, and require no further description.

IX. THE ENON CONGLOMERATE.

One of the most important formations for the purpose of the present investigation is the Enon Conglomerate. It is unnecessary here to recapitulate the evidence on which this deposit has been correlated with the marine Cretaceous strata of the Uitenhage Series: this correlation may be taken as fully established. Within the area here dealt with, almost all the deposits of this age are of a terrestrial and torrential character, and were apparently formed under conditions very similar to those now prevailing in the district. At any rate, it is sometimes difficult to distinguish the more weathered portions of the Enon Conglomerate from the coarse gravels of recent and subrecent origin which cover such great areas in the valleys and lower parts of the district. A careful examination, however, shows that the character of the pebbles is different: that is to say, they have been derived for the most part from different formations, as will later be explained in detail.

In the district under consideration there are three disconnected patches of Enon Conglomerate: a small one north-west of Worcester, a larger one running more or less along the course of the Nuy River, and a very large spread stretching from Robertson to Ashton. This outcrop is roughly oval in shape, and measures about 15 miles in length by 6 miles in width.

The Enon Conglomerate is well seen at Worcester Station, resting unconformably upon Ecca Sandstone. The pebbles here average about 3 inches in diameter, and are embedded in a reddish sandy matrix, which appears to be much weathered. The pebbles are almost wholly composed of hard, dark grits. Much fresher material can be obtained from an excavation recently made close to the new reservoir-dam, north-west of the town, and many blocks have been used in the construction of the dam. The conglomerate is here extraordinarily hard, and the pebbles are on the average somewhat smaller, so that it can be dressed into hand-specimens. The cement is partly ferruginous and partly calcareous. The conglomerate is also exposed in many places in the sluits before mentioned, but is here much weathered. The pebbles are everywhere almost exclusively hard, dark-green, grey, and red grits and rocks of a somewhat jaspery appearance. It is noticeable that the pebbles are very frequently bent, fractured, faulted, and indented, indicating pressure, as in the Polygenetic Conglomerate of Cumberland, to which this rock shows a striking resemblance. It is highly probable that most, if not all, of the rounded gravelly

hills north-west of Worcester really consist of Enon Conglomerate, with perhaps a thin coating of recent gravels; but, in the absence of exposures, it is impossible to decide this point with certainty, owing to the before-mentioned difficulty of distinguishing between the weathered Enon and the newer gravels.

Prof. E. H. L. Schwarz[1] has mapped and described as Enon Conglomerate a patch of gravel on the farm Lange Kloof (Geol. Surv. Map, Sheet 4), east of the Hex River; he refers to it as 'an exposure of gravel, evidently very old, but of which the pebbles are made of slate.' Unfortunately, owing to bad weather and floods in the Hex River, I was unable to visit this interesting and important exposure; but, judging from a comparison of the published description with what is seen elsewhere in the neighbourhood, I feel the gravest doubts whether this gravel is of Cretaceous age, as claimed by Prof. Schwarz. The absence of slate in the conglomerate at Worcester is noteworthy, and it is improbable that there would be so complete a difference of composition in so short a distance (less than 5 miles), especially as the Enon Conglomerates of Robertson and Ashton (30 and 40 miles away respectively) are exactly like those at Worcester, and contain no slate.

The small patch of Enon Conglomerate west of Robertson calls for no special remark, but in connexion with the large expanse of conglomerate east of the town a most important question arises. On the map of the Geological Commission, on the farms De Hoop and Aasvogels Nest, the conglomerate is shown, doubtfully, overlapping the fault, and resting directly upon Malmesbury Beds. If correct, this observation fixes the age of the fault as between Ecca and Enon, a result diametrically opposed to my observations elsewhere. I therefore examined this region most critically and carefully, and came to the conclusion that this mapping is unjustified by the evidence. The ground is very obscure, and there are no exposures in the form of excavations.

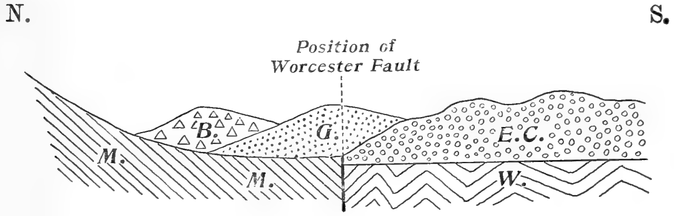
The Malmesbury rocks here form fairly high ground, with a steep slope, in fact a kind of escarpment, and on the next farm, Klaas Voogds Rivier, a curious wedge of Witteberg Beds comes in along the fault, and makes a conspicuous feature in the form of a rocky ridge. On De Hoop and Aasvogels Nest low rounded hills of gravel lie at the foot of the escarpment, and the northernmost of these certainly lie to the north of the fault. But these hills do not all consist of the same kind of material: the southern hills are undoubtedly Enon Conglomerate, but the hills north of the fault-line consist of quite different material, without the characteristic red pebbles of the Enon Conglomerate. The last hill of all, at the foot of the escarpment, is different again, being composed of large blocks

---

[1] 'Geological Survey of the Divisions of Tulbagh, Ceres, & Worcester' 10th Ann. Rep. Geol. Comm. Cape Colony, 1905, p. 289.

of Table Mountain Sandstone, which is not seen in the southern hills. It is quite clear that the material of which these hills are composed has been derived from at least three sources; and, from a careful examination, it appears certain that the gravels are successively newer towards the north. Fig. 2 shows the interpretation of the section which I adopted, after a critical examination in company with Dr. Melle, of Robertson, who is well acquainted with the geology of the neighbourhood. Of course, in this section the exact position of the fault is hypothetical, but compass-bearings of points where it is known give the general position with fair accuracy. It must come somewhere under the gravel-ridge marked G, which obviously overlies the Enon Conglomerate, and is overlain in turn by the coarse breccia B.

Fig. 2.—*Diagrammatic section through the southern part of the farm De Hoop, 3 miles east-north-east of Robertson.*



[M.M.=Malmesbury Slates. W=Witteberg Slates. E.C.=Enon Conglomerate. G=Recent gravel. B=Scree-breccia, with large blocks of sandstone.]

I conclude, therefore, that the Enon Conglomerate does not extend over the line of the fault on to the Malmesbury Beds, but is cut off by the fault on the northern side.

It is of interest to note that the Enon Beds of this area are not wholly conglomeratic; but near Klaas Voogds Station there is a development of fine grey or white sandstone, which shows some approximation to the more normal marine Cretaceous deposits of the Uitenhage district. This is probably the westernmost point to which the marine Uitenhage facies has been traced. Unfortunately, no fossils were found here.

X. The Ashton District.[1]

Ashton Station, on the New Cape Central Railway, lies about 12 miles east of Robertson, and from it an important road leads through Kogmans Kloof to the town of Montagu, which lies on the other side of the Langebergen. The general character of the country is very similar to what is seen farther west, but on the whole the topography is simpler.

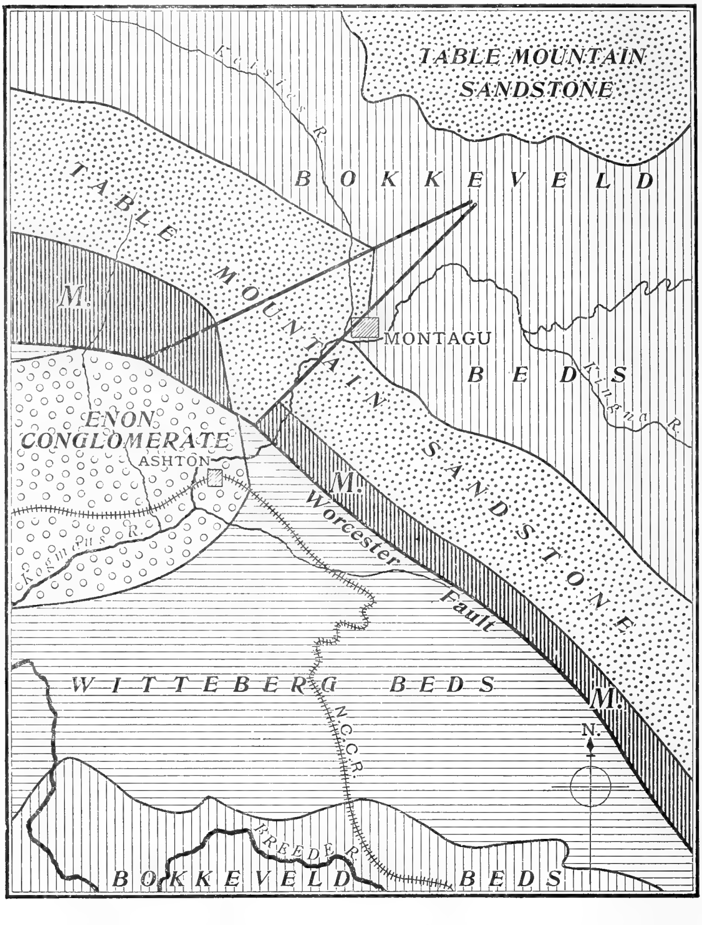
The belt of Malmesbury rocks is here much narrower, being not

---

[1] See Cape Colony Geol. Surv. Map, Sheet 2.

much more than half a mile wide where cut through by the Kogmans River, which affords a very good and nearly continuous section. In the right bank of this river, near Ashton Station, is a section of Enon Conglomerate, which is by far the largest and clearest in the whole district. Some valuable information was also obtained from a well sunk by Mr. J. O'Connor, of Ashton, on the west of the Kogmans River, by the side of the main road to

Fig. 3.—*Geological map of the district round Montagu and Ashton.*



[The geological boundaries in this map, with the exception of those in the immediate neighbourhood of Montagu and Ashton, are copied from the published map of the Geological Commission of the Cape Colony, Sheet 2.—M. = Malmesbury Series.]

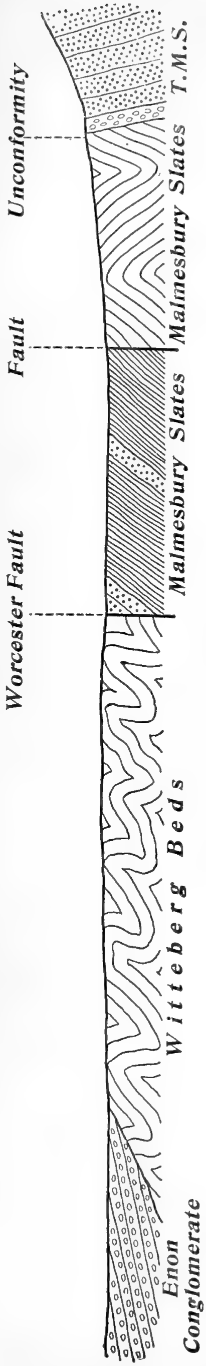


Fig. 4.—*Diagrammatic section along the banks of the Kogmans River.* (*Length=about 2000 yards.*)

[T.M.S.=Table Mountain Sandstone.]

Robertson. This well passed through about 60 feet of Enon Conglomerate, and a fine typical collection of pebbles could here be examined in detail.

The general structure of this district is simple, but of considerable interest; and its principal features can be made out from an inspection of the small map (fig. 3, p. 722). At Kogmans Kloof there is a noticeable kink in the general trend of the Langebergen Range, and this kink is accompanied by what appears to be a thrusting forward of the Cape rocks towards the south-west. On the right bank of the river, just below the mouth of the pass, the Enon Conglomerate appears to be in contact with Table Mountain Sandstone; but, unfortunately, it is impossible to determine what underlies the conglomerate at this point. There can, however, be no reasonable doubt that here, as elsewhere, it rests on Witteberg Beds: this question will again be referred to later. The position of this mass of Table Mountain Sandstone is doubtless due to two nearly parallel faults, the more important running nearly along the line of Kogmans Kloof towards Montagu, while the second follows closely the line of the upper part of Wild Paarde Kloof and crosses the Keisies River to the north-west of the farm Uitvlugt. These are tear-faults, and between them a block of Table Mountain Sandstone about 2 miles wide has been pushed nearly a mile to the south-west. This faulting is of earlier date than the Enon Conglomerate.

The banks and bed of the Kogmans River, from near Ashton Station to the mouth of Kogmans Kloof, afford a very clear section in which the relations of the different rock-groups can be made out with certainty. This is illustrated by fig. 4. The Enon Conglomerate, when best exposed for a thickness of about 40 feet, consists of large rounded and subangular boulders embedded in a red sandy matrix: it shows distinct bedding, with a gentle dip to the south. On the left bank of the river it is clearly seen lying on Witteberg Beds.

which are here reddish shales with occasional bluish grit-bands, intensely folded and contorted. This folding is of a very peculiar character, since many of the folds are in the horizontal position, with their axial planes vertical. It is evidently impossible to represent this in a diagram. Sometimes, for considerable distances the strike of the beds is nearly north-east and south-west, that is, at right angles to the normal strike of the district; but the general trend appears to be north-west and south-east. In the arches of the anticlines are occasional patches of crush-breccia. The total width of the outcrop of the Witteberg Beds in the river is about 1000 yards.

The exact position of the great fault between the Witteberg and the Malmesbury Beds is very clearly indicated, and the strikes of the two series are quite different. The structure of the Malmesbury Series is much simpler, and the dips more uniform; the folds which can occasionally be seen are not of much importance. The rocks of this series are for the most part silvery or blue slates, weathering yellow, with occasional grit-bands. The width of the outcrop of Malmesbury Beds is here about 800 yards, and at one point a fault is very clearly seen in the middle of the series.

The junction with the Table Mountain Sandstone is almost vertical, and the lowest bed of the latter, about 4 feet thick, appears to be a basal conglomerate of quartz-pebbles, which has been afterwards infilled with vein-quartz. It presents a strong superficial resemblance to the bankets of the Rand, and has been unsuccessfully prospected for gold. The Table Mountain Sandstone itself is here of the usual character, and calls for no comment.

This section is of especial interest, since it displays very clearly and in a compact form a typical series of the rocks of this district. Incidentally it may be mentioned that the published map of the Geological Commission of the Cape of Good Hope, on the scale of $3\frac{3}{4}$ miles to the inch, is incorrect at this point, since it shows the river flowing over Malmesbury Slates and Enon Conglomerate only, whereas the Witteberg Slates are seen in the banks of the stream for nearly 1000 yards. It appears, therefore, that there is actually a narrow tongue of Witteberg Beds running between the outcrop of the conglomerate and the fault, across the stream; and the Enon Conglomerate is here not cut off by the fault, although it comes against it a little farther north.

The fine exposure of Enon Conglomerate on the right bank of the river forms a prominent cliff about 40 feet high, of which the uppermost 10 feet or so is recent alluvium, consisting of yellow gravel with very big boulders of Table Mountain Sandstone up to a cubic yard in bulk. About 30 feet of the conglomerate is exposed, consisting of boulders measuring as much as 1 cubic foot, embedded in a reddish sandy matrix. Bedding is distinctly shown, and the dip is about 10° southwards. The boulders in this conglomerate consist exclusively of sandstones and grit, mostly resembling those of the Witteberg and Ecca Series; and, despite the most diligent search, no fragments of Malmesbury rocks could be found.

A careful examination was also made of a well, sunk by Mr. J. O'Connor about half a mile west of Ashton Station, by the side of the main road to Robertson. The following section was compiled from personal inspection, and from data supplied by Mr. O'Connor:—

	Thickness in feet.
Soil, clay, etc.	30
Hard marly clay	25
Boulder-bed	5
Enon Conglomerate	60

The recent deposits of soil and clay are here of extraordinary depth, no less than 60 feet being passed through. The lowest 5 feet of this consists of a bed of big boulders, chiefly of Table Mountain Sandstone, well rounded by water-action. A very large pile of pebbles from the Enon Conglomerate was carefully examined. They range up to 18 inches in diameter, and the largest came from the bottom of the well. Abundant specimens of Dwyka Conglomerate were observed, while the blocks of sandstone closely resemble the grit-bands in the Witteberg Series, and are quite unlike the Table Mountain Sandstone. It is an observation of the utmost significance that the Enon Conglomerate of this neighbourhood contains no fragments of Malmesbury rocks, and this statement is fully confirmed by Mr. O'Connor, who has an intimate knowledge of all the rocks of this neighbourhood. There is also some evidence that boulders of Dwyka rocks are more abundant below, and those of Witteberg rocks above.

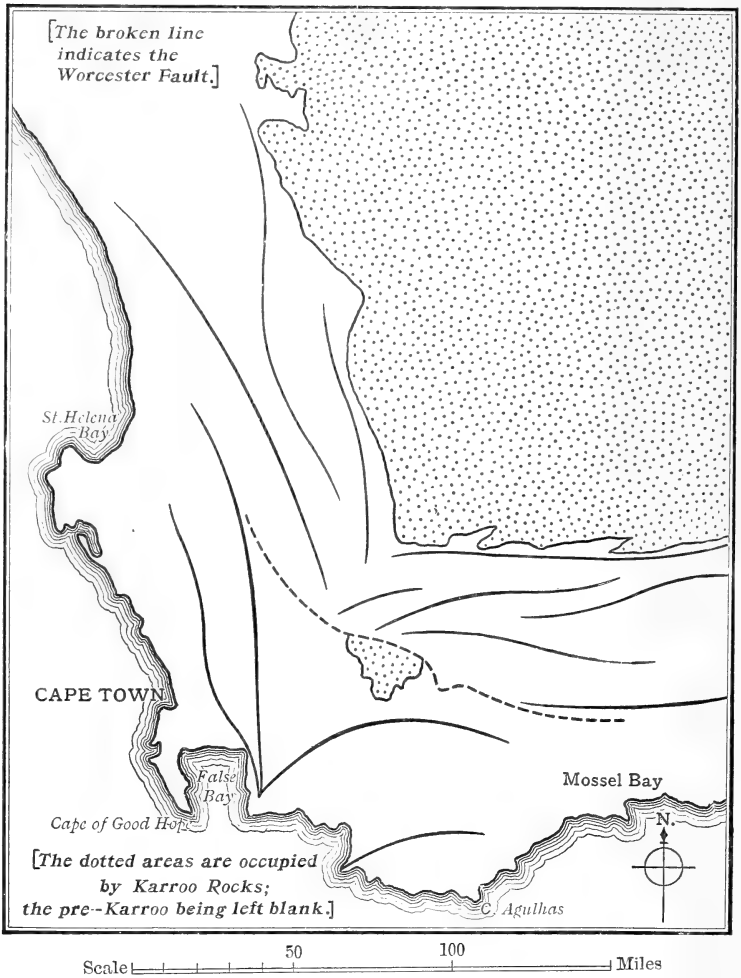
XI. General Conclusions.

The dominant tectonic feature of Cape Colony is the occurrence of conspicuous lines of folding, which are very clearly indicated by the outcrop of the rocks of the Cape System. Over an immense area in the centre and north of the Colony the rocks of the Karroo System are horizontal; but, towards the south and west, they begin to show increasingly steep dips, and at the margin of the outcrop they are very highly inclined along with the Cape rocks. In the south the two systems are apparently conformable, but towards the north there is a conspicuous overlap of the Karroo System. The markedly rectangular form of the south-western corner of the Karroo outcrop is intimately connected with the direction of the principal lines of folding. These are divided into two well-defined sets: near the west coast the trend-lines run north and south, while near the south coast they run east and west. These are called by Dr. Rogers the Cederbergen and Zwartebergen Series respectively.

These two sets of folds come together in the neighbourhood of Worcester and Robertson, and it is necessary to consider the nature of their junction or syntaxis. The matter is further complicated by the occurrence of the great Worcester-Swellendam Fault, which cuts obliquely across the syntaxis, and has brought down a small area of Karroo rocks on its southern, or downthrow side. It is

evidently, therefore, of the first importance to determine, if possible, the age of this fault.

Fig. 5.—*The dominant trend-lines of the south-western part of Cape Colony.*



Furthermore, a careful study of a geological map of the region shows that the two sets of folds may be regarded as spreading out in a somewhat fan-like manner from a point or region situated somewhere in the neighbourhood of Somerset West, on the east side of False Bay: if a line is drawn from this point in a north-easterly direction, the folded mountain-chains are arranged more or less symmetrically with regard to it, and the Worcester Fault cuts it

approximately at right angles. It is also noticeable that the fault is curved, running nearly parallel at either end to each of the sets of folds, and changing its general direction from north and south at one end to east and west at the other. From these considerations, it is evident that the fault has a close genetic connexion with the folding.

Although these two phenomena are obviously connected, it must not be assumed that they are contemporaneous: in fact, such is clearly not the case. From a study of the structure of the rocks of the Cape System on either side of the Worcester Fault, there can be little doubt that the faulting is in the main later than the folding, although it is probable from other considerations that no long interval of time separated them.

The faulting is certainly later than the rocks of the Ecca Series, since the Dwyka Conglomerate and Ecca Sandstone and Shale are brought into contact with Malmesbury and Cape rocks. The question next arises, whether the fault is or is not newer than the Enon Conglomerate; and to this it is somewhat more difficult to give a conclusive reply, since some of the evidence is not very clear. The most important fact to determine for this purpose is whether or not the Enon Conglomerate is cut by the fault, and as to this some doubt has hitherto existed. There is no doubt that the fault forms, in a general way, the northern boundary of the Enon facies of the Cretaceous in this region[1]; but, on the maps of the Cape Geological Commission, the conglomerate is mapped in places as just overlapping the fault, apparently for a few hundred yards. This, on the face of it, is improbable: if the present distribution of the conglomerate is independent of the fault, it is unlikely that its boundary would follow so closely the line of the fault for scores of miles, and overlap it occasionally for a few yards only. There is no real field-evidence for this interpretation, and the general form of the patches of Enon Conglomerate is very strong presumptive evidence in favour of their truncation on the northern side by the fault, exactly in the same way as the Karroo rocks are truncated. Hence, we may conclude almost with certainty that the Worcester-Swellendam Fault is, at any rate in part, newer than the Lower Cretaceous.

Another line of argument may also be pursued, namely, that derived from the character of the blocks and pebbles of which the Enon Conglomerate is composed. In the first place, so far as my own most careful observations go, the Enon Conglomerate at Worcester, Robertson, and Ashton does not contain pebbles of the Malmesbury rocks. The only possible exception to this is the somewhat doubtful case described by Prof. Schwarz at Lange Kloof near the Hex-River Pass, and as to this I am frankly sceptical,

---

[1] Dr. Rogers & Mr. Du Toit consider that the Enon Beds of the Oudtshoorn region were formed in a different basin of deposition; see their Geology of Cape Colony' 2nd ed. (1909) p. 321.

since it is obviously so different from all the other occurrences in the neighbourhood. I paid especial attention to this point in the exposures of Enon Conglomerate near Robertson and Ashton, and was unable, after several prolonged searches, to find a single piece of Malmesbury slate.

But a further point may also be put forward: the coarse grits and quartzites of the lower part of the Table Mountain Series could not be identified with certainty in the Enon Conglomerate. It appeared to me, and to the local observers who were kind enough to assist me, that all the blocks in the Enon Conglomerate could be referred to the Witteberg and Ecca Series (including, of course, in this last designation the Dwyka Conglomerate). This is an argument which must not be pushed too far, since it is obviously impossible to state dogmatically that every pebble of quartzite or of sandstone is Witteberg or Ecca Sandstone and not Table Mountain Sandstone. Still, it may be safely asserted that the general facies of the pebbles in the Enon Conglomerate led to the belief that the Table Mountain Sandstone is not represented therein.

If these facts are admitted, we are at once led to an important conclusion, namely: that at the time of the formation of the Enon Conglomerate the Malmesbury Series and the lower part of the Cape System were not exposed in the district here investigated.

In order to appreciate the full significance of this conclusion, we must now consider what were the conditions under which the Enon Conglomerate was formed. It is obviously a torrential deposit, composed of well-rounded blocks, embedded in a sandy matrix, with occasionally, and especially in the higher part of the succession, beds of a finer texture and sandy or marly character. This deposit has evidently been formed under terrestrial conditions, and it is very similar to the deposits now being formed, or which have recently been formed, at the foot of the mountain-slopes of the region, and especially where the larger streams cut through the ranges. Reference has already been made to the difficulty of distinguishing between weathered Enon Conglomerate and some of these recent deposits, and their manner of formation must have been very similar. When bedding is visible in the Enon Series, it is often evident that the material came from the north, showing that at that time also the high ground lay in that direction.

However, it appears improbable, from two independent lines of argument, that the Enon Conglomerate was formed in exactly its present position. In the first place, it has been shown that the Enon Conglomerate has taken part in some, at any rate, of the movement of the Worcester Fault, hence it must have been formed at a higher level: and secondly, the materials of the conglomerate are not of a character consistent with formation at the present level.

It may be suggested, then, that at the time of the formation of the Enon Conglomerate a range of mountains existed in approximately the same geographical position as the Langebergen, but at a higher level, so that it was composed of Witteberg and Karroo

rocks. These were undergoing rapid denudation, and the denuded material accumulated at the foot of their steep southern slope, most probably in disconnected basins, corresponding more or less to the present distribution of the conglomerate, but of larger size.

In order to gain some idea of the height above the present level at which this denudation and accumulation took place, we must take into account the thickness of the Cape System. According to the best authorities, the Table Mountain Sandstone is about 5000 feet thick, the Bokkeveld Series 2500 feet, and the Witteberg Series also 2500 feet. On the assumption that only Witteberg Beds were exposed, the ground-surface must then have been some 7000 or 8000 feet higher than at present. This height need not necessarily have been absolute height above sea-level, but may be referred to some arbitrary datum-line—for example the base of the Cape System, which may then have been absolutely either higher or lower than at present.

According to this view, then, the Enon Conglomerate resulted from the denudation of a land-surface, possibly a mountain-range, formed of Witteberg and Karroo rocks, while the underlying pre-Cambrian rocks were not exposed. There is some evidence that Dwyka Conglomerate is more abundant in the lower part of the conglomerate, and Witteberg Beds in the upper part, thus indicating a progressive uncovering of lower and lower beds; but on this point much more work is needed before it can be regarded as established. Then, after the formation of the Enon Conglomerate, the major portion at any rate of the fault-movement took place, bringing Enon Conglomerate in places into juxtaposition with Malmesbury rocks. This fixes the age of the fault as post-Cretaceous.

The disposition of the minor lines of folding in the region to the south of the fault is in favour of the view that a close connexion exists between the folding and the faulting. North of the fault the strike of the Cape rocks of the Langebergen is uniformly east and west, and the dip is steeply northwards. South of the fault, however, they are ridged up into a series of sharp anticlines and synclines, with axes running approximately north-north-east and south-south-west, and occasionally accompanied by parallel faults: as, for example, west of Lady Grey. The trend-lines of these structures are, therefore, nearly at right angles to the principal fault. It appears, then, that when the region to the south of the fault sank down, it also underwent a sort of lateral crumpling due to compression.

Let us now turn to a consideration of the events which succeeded the formation of the Enon Conglomerate. As we have already seen, the evidence suggests that the conglomerate was formed on an old land-surface, composed of Ecca, Witteberg, and Bokkeveld rocks. Then, as a result of earth-movement, or possibly on account of a release of pressure, subsidence took place along a fault-line (which had probably been already initiated), resulting in the formation of the great Worcester-Swellendam Fault. This fault must be

regarded as a fracture and depression occurring in the triangular area between two sets of folds at right angles one to the other. A very similar phenomenon is the well-known area of the Warm Bokkeveld, which is also a depressed region, and immediately north of it is a small patch of Karroo rocks, let down by a fault on the north-eastern side. This fault runs parallel with the Worcester Fault, and is probably due to the same set of causes.

These folds are obviously due to lateral thrust, since they are clearly asymmetric, but it is still a matter of discussion from which side the greater pressure came. Prof. Schwarz[1] has put forward the view that the folding of these ranges is due to the intrusion of the vast sheets of dolerite in the Karroo System, thus implying that the maximum pressure came from the interior. This idea is ingenious, but (so far as we know at present) inconsistent with the field evidence.[2] The general structure of the region and the disposition of the folded chains can be much more easily explained on the supposition of pressure acting from the exterior towards the interior, and consisting of two sets of thrusts:—one towards the north, which produced the east-and-west folds of the Langebergen and other parallel ranges, the Zwartebergen folds of Rogers; the other towards the east, giving rise to the ranges of the west-coast region, the Cederbergen folds. These two sets of thrusts interfered mutually where they came in contact, in the south-western corner of the Colony, thus producing the fan-shaped arrangement of mountain-chains which is so characteristic a feature. It appears that this fault was formed subsequently to the principal period of folding, and it probably occurred when the pressure was released to a certain extent, thus allowing of a great subsidence.

This final, post-Enon, movement was evidently accompanied by considerable earth-pressure, since the pebbles of the conglomerate are commonly fractured and indented, and this process presumably took place concurrently with the formation of the fault.

To sum up: the dominant features of the geology of this region are:—

(*a*) The conspicuous folding, of post-Karroo age, in part pre-Cretaceous: this led to the formation of mountain-chains in two sets, east-and-west and north-and-south respectively, with a syntaxis in the south-western corner of Cape Colony.

(*b*) A post-Cretaceous period of movement, which resulted chiefly in a great subsidence to the south of a fault-line cutting obliquely across the syntaxis; accompanying or preceding this were minor lines of crumpling on the downthrow side of the fault, leading to the formation of subsidiary folds striking north-east and south-west, or thereabouts. It is impossible to say with certainty whether the faulting was wholly subsequent to, or in part con-

---

[1] 'Causal Geology' London, 1910, pp. 141–43 & fig. 10.

[2] A. W. Rogers & A. L. Du Toit, 'Geology of Cape Colony' 2nd ed. (1909) pp. 123-24 & fig. 9.

temporaneous with the formation of the Enon Conglomerate, but it was certainly for the most part later than the formation of this deposit.

One more point still remains to be dealt with, that is to say, the extent of the Worcester Fault. Many estimates have been given of the maximum throw of this fault as at present existing, and it is undoubtedly very great. At its most favourable development it brings into contact Enon Conglomerate and Malmesbury Slate, but the throw is not necessarily represented by the thickness of all the strata which elsewhere occur between these limits. At different points the conglomerate rests upon Ecca, Witteberg, and Bokkeveld Beds; and, as we have seen, there is reason to believe that before the formation of the fault these rocks had undergone very considerable folding and denudation, so that it is obviously incorrect to add together the total thickness of the missing formations to obtain the throw. We can only say with absolute certainty that the throw must be at least equal to the difference of level of the upper surface of the Malmesbury rocks on either side of the fault, and there is unfortunately no means of measuring this directly. The lowest bed on which Enon Conglomerate rests directly is the Bokkeveld, so the minimum throw must be at least equal to the sum of the thicknesses of the Table Mountain Sandstone and part of the Bokkeveld, but this need not necessarily be much more than 5000 feet. This may be regarded as the lower limit. On the other hand, the higher limit is, as explained above, the total thickness of all the strata between the Malmesbury Series and some horizon in the Ecca Series.

The thicknesses may, then, be tabulated as follows:—

	Feet.
Ecca Sandstone	1000
Dwyka Conglomerate	2000
Witteberg Series	2500
Bokkeveld Series	2500
Table Mountain Sandstone	5000
Total	13,000

It is here assumed that the highest Ecca bed seen along the fault is 1000 feet above the top of the Dwyka, and this, although a very rough estimate, is probably not far from the truth.

Hence we see that the throw of the fault must be something between 5000 and 13,000 feet, and in all probability it is nearer to the larger figure than to the smaller. It is of course possible, and indeed highly probable, that the throw of the fault varies, since it has a visible length of some 70 miles and may be continued much farther. At any rate, it may safely be said that in the middle of its length, near Robertson, the throw is probably something like 10,000 feet, and perhaps more, a figure which is certainly large enough to justify its inclusion among the greatest dislocations at present known to geological science.

In conclusion, I have much pleasure in expressing my indebtedness to those gentlemen whose kind co-operation did so much to render this work possible: to Dr. Melle, of Robertson, and Mr. J. O'Connor, of Ashton, I owe a debt of gratitude for hospitality and help in the field; but above all, my thanks are due to Dr. A. W. Rogers, on whose suggestion the work was undertaken, and without whose help and encouragement it could not have been carried out. To these and other friends who have aided me by advice and criticism, I tender my most hearty thanks.

EXPLANATION OF PLATE LI.

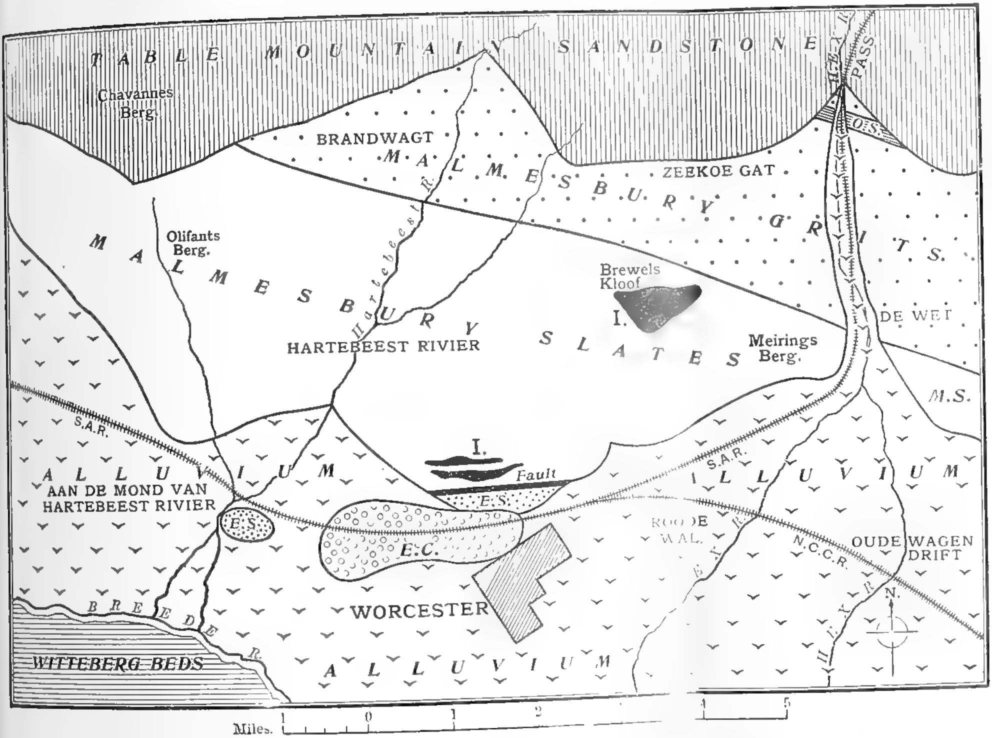
Geological map of the neighbourhood of Worcester (Cape Colony), on the scale of 1·8 miles to the inch, or about 1 : 115,000.

Discussion.

Mr. G. W. Lamplugh said that, for him, the chief interest of the paper lay in the statements regarding the relation of the Enon Conglomerate to the Worcester Fault. He paid a flying visit to the Worcester district six years ago under the guidance of his friend Dr. A. W. Rogers, and he then gathered, without, however, himself seeing the evidence, that the Enon Conglomerate was known to rest directly upon the Malmesbury rocks north of the fault and to contain pebbles from these rocks. This implied that the fault was believed in the main to be pre-Enon, though it was recognized that there were minor movements along it at a later date. Important conclusions as to the geological history of South Africa generally had been based on this supposed relationship, which was now challenged. If the Author was able to prove that the previous investigators were wrong in their observations, he had done good work in South Africa; but, unless his evidence was perfectly clear, he must be prepared for sharp criticism, as the matter was of far-reaching consequence.

Dr. J. W. Evans thought that the Worcester-Swellendam Fault might be an 'isostatic' fault, determined by the gradual rise of the high ground on the north-east and depression of the sea-floor on the south-west, as the former was worn down by subaërial agencies and the resulting material accumulated on the latter. It often happened that a certain amount of basement-conglomerate occurred on the upthrow side of such a fault, and that might be the case near Worcester, even if the movement continued after the deposition of the Enon Conglomerate. With reference to the conflict of evidence as to the occurrence of Malmesbury rocks in the conglomerate, he suggested that, even on the supposition that the greater portion of the conglomerate was deposited before these rocks were laid bare, some of it might date from a later period when they were exposed at the surface.

The Author, in reply to the points raised by Mr. Lamplugh, pointed out that post-Cretaceous faulting did not necessarily imply



GEOLOGICAL MAP OF THE NEIGHBOURHOOD OF WORCESTER (CAPE COLONY).

[O.S. = Ottrelite-schist ; E.S. = Ecca Sandstone ; E.C. = Enon Conglomerate ; I. = Igneous rocks.]

that the Cretaceous rocks were deposited at a height above their present level equal to the total throw of the fault. He had no doubt that a large part of the movement was of earlier date, and considered that a post-Cretaceous movement of 2000 or 3000 feet was sufficient to account for the phenomenon. He certainly did not believe that the Cretaceous rocks ever extended over the Karroo, and regarded the Enon Conglomerate as a torrential deposit formed at the foot of a mountain-escarpment, probably a fault-scarp. He much regretted that he had had little opportunity of discussing the matter with Dr. Rogers, and awaited with great interest the opinion of South African geologists on the paper. In reply to Dr. Evans, he stated that conglomerates do exist to the north of the fault, but these are of quite different character and undoubtedly recent. In conclusion, the Author admitted that the view put forward by the Cape geologists offered an easier interpretation, but he did not believe it to be correct.

GENERAL INDEX

TO

THE QUARTERLY JOURNAL

AND

PROCEEDINGS OF THE GEOLOGICAL SOCIETY.

END OF VOL. LXVII.

PRINTED BY TAYLOR AND FRANCIS, RED LION COURT, FLEET STREET.

ADMISSION AND PRIVILEGES

OF

FELLOWS OF THE GEOLOGICAL SOCIETY OF LONDON.

Every Candidate for admission as a Fellow must be proposed by three or more Fellows,
who must sign a Certificate in his favour. The Proposer whose name stands first upon
he Certificate must have a personal knowledge of the Candidate.

Fellows on election pay an Admission Fee of Six Guineas. The Annual Contribu-
ion paid by Fellows is Two Guineas, due on the 1st of January in every year, and
ayable in advance; but Fellows elected in November or December pay no Contribu-
ion for the current year. The Annual Contribution may, at any time, be compounded
or by a payment of Thirty-Five Pounds.

The Fellows are entitled to receive gratuitously all the volumes or parts of volumes
f the Quarterly Journal of the Society that may be published after their election,
o long as their Annual Contributions are paid; and they may purchase any of the
ublications of the Society at a reduction of 25 per cent. under the selling-prices.

The Library is open daily to the Fellows between the hours of 10 and 5 (except
during the fortnight commencing on the first Monday in September; see also
ext page), and on Meeting-Days until 8 P.M. Under certain restrictions, Fellows
re allowed to borrow books from the Library.

Publications to be had of the Geological Society, Burlington House.

QUARTERLY JOURNAL. (Vols. III to LXVII, inclusive.)

Price to Fellows, 13*s.* 6*d.* each (Vols. XV, XXIII, XXX, and XXXIV to LXVII, 16*s.* 6*d.*), in cloth.

GENERAL INDEX TO THE FIRST FIFTY VOLUMES OF THE QUARTERLY JOURNAL (1845–1894). Part I (A–La). Part II (La–Z). Price 5*s.* each. To Fellows 3*s.* 9*d.* each. [Postage 3*d.*]

GEOLOGICAL LITERATURE added to the Geological Society's Library during the years ended December 31st, 1894–1910. Price 2*s.* each. To Fellows, 1*s.* 6*d.* each. [Postage 3*d.*]

THE HISTORY OF THE GEOLOGICAL SOCIETY OF LONDON, by H. B. WOODWARD, F.R.S. Price 7*s.* 6*d.* To Fellows, 6*s.* [Postage 6*d.*]

THE CENTENARY OF THE GEOLOGICAL SOCIETY OF LONDON, recorded by W. W. WATTS, F.R.S. Price 2*s.* net. [Postage 3*d.*]

HUTTON'S 'THEORY OF THE EARTH,' Vol. III., edited by Sir ARCHIBALD GEIKIE, D.C.L., F.R.S. Price 3*s.* 6*d.* To Fellows, 2*s.* [Postage 4*d.*]

THE GEOLOGY OF NEW ZEALAND. Translated by Dr. C. F. FISCHER from the works of MM. HOCHSTETTER & PETERMANN. With an Atlas of Six Maps. Fellows may purchase one Copy of this Book at 2*s.* Additional Copies will be charged 4*s.* [Postage 5*d.*]

CONTENTS.

PAPERS READ.

[No. 269 of the Quarterly Journal will be published next February.]

[The Editor of the Quarterly Journal is directed to make it known to the Public that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

⁂ The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

The Library and Museum at the Apartments of the Society are open every Weekday from Ten o'clock until Five, except during the fortnight commencing on the first Monday in September, when the Library in closed for the purpose of cleaning; the Library is also closed on Saturdays at One P.M. during the months of August and September. It is open until Eight P.M. on the Days of Meeting for the loan of books, and from Eight P.M. until the close of each Meeting for conversational purposes only.

PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1910–1911.

November 9th, 1910.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President,
in the Chair.

Herbert Arthur Baker, B.Sc., Heath Lodge, Plumstead Common, Plumstead, S.E.; Arthur Henry Noble, B.A., Geological Survey, 28 Jermyn Street, S.W.; Harry Benedict Wall, 8 Clarence House, Clarence Gate, Regent's Park, N.W.; and James Bull Williams, c/o James Pollock, Sons, & Co., Ltd., 3 Lloyd's Avenue, E.C., were elected Fellows of the Society.

The List of Donations to the Library was read.

The President read the following reply, which had been received to the Address of condolence submitted by the President, Council, and Fellows to H.M. the King:—

'Home Office, Whitehall,
12th August, 1910.

'Sir,

I am commanded by the King to convey to you hereby His Majesty's thanks for the Loyal and Dutiful Address of the President, Council, and Fellows of the Geological Society of London, expressing their sympathy with His Majesty on the occasion of the lamented death of his late Majesty King Edward the Seventh, and congratulations on His Majesty's Accession to the Throne.

I am, Sir,
Your obedient Servant,
Winston S. Churchill.'

The President of the
Geological Society,
Burlington House, W.

The following communications were read :—

1. 'The Rhætic and Contiguous Deposits of West, Mid, and Part of East Somerset.' By Linsdall Richardson, F.R.S.E., F.L.S., F.G.S.

2. 'Jurassic Plants from the Marske Quarry.' By the Rev. George John Lane, F.G.S.

The following specimens, photographs, and maps were exhibited :—

Specimens of Rhætic deposits and fossils from Somerset, also lantern-slides, exhibited by L. Richardson, F.R.S.E., F.L.S., F.G.S., in illustration of his paper.

A series of photographs of Jurassic plants from the Marske Quarry, exhibited by the Rev. G. J. Lane, F.G.S., in illustration of his paper.

Photographs demonstrating the recession of the Grand Pacific and Muir Glaciers between the years 1894 and 1907, exhibited by M. B. Cotsworth, F.G.S.

The new Geological Survey maps of Egypt, that on the scale of 1 : 1,000,000 being in six sheets, and that on the scale of 1 : 2,000,000 in one sheet; issued by the Survey Department of Egypt, 1910, and presented by the Director of that Department.

Fourteen sheets of the 6-inch Geological Survey Map of Scotland, issued by that Survey, and presented by the Director.

November 23rd, 1910.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President,
in the Chair.

Charles Moncrieff Piachaud Wright, c/o Messrs. Grindlay & Co., 55 Parliament Street, S.W., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'The Effects of Secular Oscillation in Egypt during the Eocene and Cretaceous Periods.' By William Fraser Hume, D.Sc., A.R.C.S., F.G.S., Director of the Geological Survey of Egypt.

2. 'The Origin of the British Trias.'[1] By A. R. Horwood. (Communicated by Prof. T. G. Bonney, Sc.D., F.R.S., F.G.S.)

---

[1] Withdrawn by permission of the Council.

The following specimens, etc. were exhibited :—

Specimens of Eocene fishes from Egypt and lantern-slides, exhibited by Dr. W. F. Hume, A.R.C.S., F.G.S., in illustration of his paper.

Rock-specimens, photographs, and lantern slides, exhibited on behalf of Mr. A. R. Horwood, in illustration of his paper.

December 7th, 1910.

Prof. W. W. WATTS, Sc.D., M.Sc., F.R.S., President,
in the Chair.

Frederick Robert Bader, M.Inst.C.E., Public Works Department, Bombay (India); Alfred William Vincent Crawley, Kilo (Belgian Congo), *viâ* Fort Portal (Uganda); Francis A. Holiday, A.R.C.S., Caledonian House, Port of Spain, Trinidad (B.W.I.); Brees van Homan, 17 Gracechurch Street, E.C.; William Jones, Assistant Demonstrator in Geology at the Imperial College of Science & Technology, Felinfoel, Llanelly (Caermarthenshire); Arthur Leonard Leach, Giltar, Shrewsbury Lane, Shooters Hill (Kent); Montagu Lubbock, M.D., F.R.C.P., 127 Mount Street, W.; Arthur Douglas Lumb, 47 Putney Hill, S.W.; William Theophilus Ord, M.R.C.S., L.R.C.P., Greenstead, Madeira Road, Bournemouth; Frank M. Preston, Assoc.M.Inst.C.E., 15 Exchange, Bradford; James Ernest Richey, B.A., Demonstrator in Geology in the University of Oxford, University Museum, Oxford; William Wilfred Samuel, Tanlan House, Llanelly (Caermarthenshire); William Pinckney Walker, Ingles, Heaton Grove, Bradford; and Stanley Dawson Ware, 4 Connaught Avenue, Mutley, Plymouth, were elected Fellows of the Society.

The list of Donations to the Library was read.

Dr. A. S. WOODWARD communicated an account of recent excavations in the cavern of La Cotte, St. Brelade's Bay (Jersey), made during the present year by the Jersey Society of Antiquaries. According to the report of Mr. E. T. Nicolle and Mr. J. Sinel, shortly to be published by the Jersey Society, the cave has yielded evidence of human habitation and traces of Pleistocene Mammalia. About a hundred flint-implements of the Mousterian type have been obtained, besides part of a molar of *Rhinoceros antiquitatis*, and both teeth and antlers of *Rangifer tarandus*. Human remains and teeth of *Bos* have also been examined and determined by Dr. C.W. Andrews and Dr. A. S. Woodward, to whom the whole of the collection of mammalian remains was referred. This being the first discovery of typical Pleistocene Mammalia in the Channel Islands, the Jersey Society hopes to proceed with the excavations as soon as possible.

Dr. A. STRAHAN, F.R.S., Treas.G.S., delivered a lecture, illustrated by lantern-slides, on the occurrence of recent shelly boulder-clay and other glacial phenomena in Spitsbergen.

The following specimens, etc. were exhibited :—

Shells from the moraine of the Sefström Glacier, Spitsbergen, exhibited, in illustration of Dr. A. Strahan's lecture, by G. W. Lamplugh, F.R.S., F.G.S.

A large series of flints, supposed to show human workmanship, from Ipswich and district, from below the Crag of Newbournian age, exhibited by J. Reid Moir.

Eoliths, etc., and water-colour drawings of the same, exhibited by Benjamin Harrison (Ightham).

Chipped flints from the bed at the base of the Norwich Crag, near Norwich, exhibited by W. G. Clarke.

Palæolithic implements from one pit in the Upper Thames Valley, exhibited by L. Treacher, F.G.S.

Eoliths from Dewlish, exhibited by C. J. Grist, M.A.

A series of evolutionary forms of eolithic and palæolithic implements from Kent, and microliths from beneath Boulder Clay at Acton (Suffolk), exhibited by F. J. Bennett, F.G.S.

Specimens showing the accidental chipping of flint, exhibited by S. H. Warren, F.G.S.

Flakes broken off flint by a cart-wheel at Hedley Lane, 1893, exhibited by E. T. Newton, F.R.S., F.G.S.

Specimens of calcareous algæ showing their importance as rock-building organisms, exhibited by Prof. E. J. Garwood, M.A., Sec.G.S.

Plants from the Lignite of Bovey and Heathfield (Devon) figured and described by Mr. and Mrs. Clement Reid, exhibited by the Director of H.M. Geological Survey.

Radioles of Triassic Echinoids, with drawings of their microstructure, by G. T. Gwilliam, F.R.A.S., exhibited by Dr. F. A. Bather, M.A., F.R.S., F.G.S.

Specimens of *Belemnites owenii* from the Oxford Clay at Fletton, near Peterborough, with pelecypods in their alveoli, exhibited on behalf of Mr. T. Plowman by G. C. Crick, A.R.S.M., F.G.S.

Rocks from Sweden collected during excursion-meetings of the International Geological Congress, 1910, exhibited by W. G. Fearnsides, M.A., F.G.S.

Slate bored by *Strongylocentrotus*, from Bantry Bay (Co. Cork), exhibited by J. Romanes, M.A., F.G.S.

Block of gypsum with a groove surrounding it, from East Bridgeford (Nottinghamshire), exhibited by Henry Preston, F.G.S.

Fossil wood and jet in a matrix of Lias, Robin Hood's Bay ; and phragmocone of belemnite from Staithes, exhibited by James Francis, F.G.S.

Specimens of *Conulus subrotundus*, exhibited by G. E. Dibley, F.G.S.

Photographs and casts illustrating the structure of glacier-ice and glacier granule-markings, exhibited by R. M. Deeley, M.Inst.C.E., F.G.S.

Lantern microscope-slides of rock-specimens, exhibited by Dr. C. G. Cullis, F.G.S.

Autograph letters of Dean Buckland, Sir Richard Owen, and Sir Henry De La Beche, etc., exhibited by E. A. Martin, F.G.S.

Photographs of relief-maps of the massifs of Mont Blanc and the Auvergne by L. J. Bardin, made before 1870, exhibited by W. P. D. Stebbing, F.G.S.

Plans of the new buildings for the Royal School of Mines, exhibited by Prof. W. W. Watts, Sc.D., F.R.S., Pres.G.S., on behalf of the Governors of the Imperial College of Science and Technology.

December 21st, 1910.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

Thomas Henry Withers, 6 Barclay Road, Walham Green, London, S.W., was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Keuper Marls around Charnwood Forest.' By Thomas Owen Bosworth, B.A., B.Sc., F.G.S.

2. 'The Relationship of the Permian to the Trias in Nottinghamshire.'[1] By Robert Lionel Sherlock, B.Sc., A.R.C.S., F.G.S.

The following specimens and lantern-slides were exhibited:—

Specimens from the Keuper Marls, etc., of the Charnwood district, and lantern-slides, exhibited by T. O. Bosworth, B.A., B.Sc., F.G.S., in illustration of his paper.

Specimens of Permian and Triassic rocks and lantern-slides, exhibited by R. L. Sherlock, B.Sc., A.R.C.S., F.G.S., in illustration of his paper.

Specimens of Triassic sandstones, etc., exhibited by Bernard Smith, M.A., F.G.S.

A quartzite fragment (probably from a Llandovery conglomerate at Broomhill Path, North Malvern), polished by slickensiding; and five stones presenting the characteristics of dreikanter, from the surface of fields near Lichfield, exhibited by E. E. L. Dixon, B.Sc., F.G.S.

---

[1] Communicated by permission of the Director of H.M. Geological Survey.

January 11th, 1911.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President,
in the Chair.

The following Fellows of the Society, nominated by the Council, were elected Auditors of the Society's Accounts for the preceding year:—George William Young and Charles Gilbert Cullis, D.Sc.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Zonal Classification of the Salopian Rocks of Cautley and Ravenstonedale.' By Miss G. R. Watney and Miss E. G. Welch. (Communicated by J. E. Marr, Sc.D., F.R.S., F.G.S.)

2. 'On a Collection of Insect-Remains from the South Wales Coalfield.' By Herbert Bolton, F.R.S.E., F.G.S., Curator of the Bristol Natural History Museum.

The following specimens and map were exhibited:—

Insect-remains from the South Wales Coalfield, exhibited by H. Bolton, F.R.S.E., F.G.S., in illustration of his paper.

Carte géologique des Hautes-Alpes calcaires entre la Lizerne et la Kander, par Maurice Lugeon, on the scale of 1 : 50,000, 1910, presented by the Author.

January 25th, 1911.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President,
in the Chair.

Philip Grimley, 15 Hermitage Road, Edgbaston, Birmingham; Edward Heron-Allen, F.L.S., F.R.M.S., 3 Northwick Terrace, N.W.; Frank Garfield Penman, M.A., Invergarry, New Barnet; Herbert Gladstone Smith, B.Sc., Assoc.R.C.S., Demonstrator in Geology in the Imperial College of Science and Technology, 85 Lancaster Road, Notting Hill, W.; Walter Campbell Smith, B.A., British Museum (Natural History), Cromwell Road, South Kensington, S.W.; and William Trenna Walker, B.Sc., Wallasey Villa, Wallasey Road, Liscard (Cheshire), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read :—

1. 'The Skomer Volcanic Series (Pembrokeshire).'[1] By Herbert Henry Thomas, M.A., B.Sc., F.G.S.

The following specimens, lantern-slides, and maps were exhibited :—

Specimens, rock-sections, and lantern-slides, exhibited by H. H. Thomas, M.A., B.Sc., F.G.S., in illustration of his paper.

Lantern-slides, illustrating South African evidence for the planetismal hypothesis, exhibited by Prof. E. H. L. Schwarz, Assoc.R.C.S., F.G.S.

A record of a period of great seismic activity, January 2nd–4th, 1911, as registered at the Station at Woodbridge Hill, Guildford, exhibited by F. Edward Norris, F.G.S.

Geological Survey of Scotland: 6-inch Map, Sheet 32 (Edinburgh) and Sheet 33 (Haddington), 1910; also 1-inch Map, Sheet 71 (Glenelg), 1910, presented by the Director of H.M. Geological Survey.

Geologische Uebersichtskarte des Königreichs Sachsen, i. M. 1:500,000, von Hermann Credner, 1910, presented by the Author.

At 7 P.M., before the Ordinary Meeting, a Special General Meeting, at which 92 Fellows were present, was held, in order to consider the following resolutions submitted to them by the Council :—

1. That the space now occupied by the Museum be made available for the extension of the Library.
2. That it is desirable that the Society's collections of Fossils, Minerals, and Rocks, with certain exceptions to be subsequently specified, be offered to one or more of the National Museums, provided that guarantees be obtained that the specimens will be properly registered and rendered available for scientific purposes.
3. That it is not desirable that the Society should accept money for any part of the collections, or in consideration of them.
4. That the Council be empowered to approach such Institution, or Institutions, with a view to carrying the above Resolutions into effect, and that the Council shall call another Special General Meeting to express approval or otherwise of the arrangement proposed.

Resolutions 1, 2, and 4 were carried unanimously, and Resolution 3 was carried by 57 Ayes to 10 Noes.

---

[1] Communicated by permission of the Director of H.M. Geological Survey.

February 8th, 1911.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

Robert Boyle, B.Sc., Assoc.M.Inst.C.E., Fernlea, 8 Parkhill Drive, Rutherglen; G. Whitfield Halse, B.Sc., c/o Edgar A. Wallis, Apartado de Correos 416, Caracas (Venezuela); John Humphreys, M.D., F.L.S., 26 Clarendon Road, Edgbaston, Birmingham; Herbert Louis Krausé, Afrikander Proprietary Mine, Klerksdorp (Transvaal); and Herbert George Robins, 2 Raymead Villas, Malling Road, Snodland (Kent), were elected Fellows of the Society.

The List of Donations to the Library was read.

Prof. T. W. Edgeworth David, C.M.G., D.Sc., F.R.S., F.G.S., gave an account of the researches pursued by him in conjunction with Mr. R. E. Priestley, Geologist to the British Antarctic Expedition of 1907–1909, in the course of that Expedition, more especially the investigations connected with Glacial Geology. The lecture, which was illustrated by a series of beautiful lantern-slides and by numerous rock-specimens collected from the Antarctic continent, was followed by a Discussion, in which Sir Ernest Shackleton, Prof. P. F. Kendall, Mr. G. W. Lamplugh, Mr. Clement Reid, Dr. Tempest Anderson, and Prof. E. J. Garwood took part.

ANNUAL GENERAL MEETING,

February 17th, 1911.

Prof. W. W. WATTS, Sc.D., M.Sc., F.R.S., President, in the Chair.

REPORT OF THE COUNCIL FOR 1910.

THE Society shared in the national mourning occasioned by the untimely decease of His Majesty, King Edward VII. The President gave expression to the sorrow felt by the Fellows, by postponing *sine die* the Meeting which had been arranged for May 11th, 1910. At a later date, the President and Council, on their own behalf and on that of the Fellows, presented an Address to King George V, expressing their respectful condolence with him on the death of the late Monarch, and welcoming His Majesty's accession to the Throne. The text of this Address, to which a gracious reply was received, will be found at p. xcii of the Proceedings of the last Session (Q. J. G. S. vol. lxvi, 1910).

Although there were fewer new Fellows elected in 1910 than during the previous year, a slight increase in the total number of Fellows can still be recorded. In 1910, the Fellows elected numbered 48 (as compared with 64 in 1909), and 35 of these paid their Admission Fees before the end of the year. Moreover, 21 Fellows who had been elected in 1909 paid their Admission Fees in 1910, making the total Accession of new Fellows during the twelve months under review amount to 56.

Setting against this number a loss of 51 Fellows (24 by death, 18 by resignation, and 9 by removal from the List, under Bye-Laws, Sect. VI, Art. 5), it will be seen that there is a net increase in the Number of Fellows of 5 (as compared with an increase of 11 in 1909, and of 5 in 1908).

The total Number of Fellows is thus increased to 1299, made up as follows:—Compounders 252 (6 less than in 1909); Contributing Fellows 1025 (14 more than in 1909); and Non-contributing Fellows 22 (3 less than in 1909).

Turning to the Lists of Foreign Members and Foreign Correspondents, the Council have the rare pleasure of stating that no losses have been experienced during the year. The two vacancies in the List of Foreign Correspondents which were left at the end of 1909, were in due course filled by the election of Prof. F. A. Forel and Dr. A. E. Törnebohm, making both Lists complete.

With regard to the Income and Expenditure of the Society during 1910, the figures set forth in detail in the Balance-Sheet may be summarized as follows:—The actual Receipts (excluding

the Balance of £178 18*s.* 2*d.* brought forward from the previous year and £100, the amount of the Hannah Bequest) amounted to £3159 17*s.* 2*d.*, being £1 5*s.* 2*d.* more than the estimated Income. On the other hand, the total Expenditure during the same year amounted to £2985 16*s.* 2*d.*, being £101 1*s.* 10*d.* less than the estimated Expenditure for the year and £174 1*s.* 0*d.* less than the actual Receipts, the year closing with a Balance in hand of £352 19*s.* 2*d.*

In the course of April, 1910, a sum of £100 was received from the executors of the late Mr. Robert Hannah, F.G.S., a bequest to which no restrictive conditions whatever were attached.

The Committee appointed by the Council towards the end of January 1910, to consider the question of the transference of the Museum, with which is bound up the greatly needed extension of the Library, held several sittings; and, their conclusions having been endorsed by the Council, certain resolutions of Council were submitted to a Special General Meeting of the Fellows, held on January 25th, 1911. The result of that Meeting, as also the full text of the resolutions, appears on p. vii of the current Proceedings.

The Council have to announce the completion of Vol. LXVI and the commencement of Vol. LXVII of the Society's Journal.

The eighth Award from the Daniel Pidgeon Trust Fund was made on March 9th, 1910, to Mr. Robert Boyle, B.Sc., who proposed to make a series of researches on the Carboniferous Building-Stones of Scotland.

The following Awards of Medals and Funds have also been made by the Council:—

The Wollaston Medal is awarded to Prof. Waldemar Christofer Brögger, in recognition of his 'researches concerning the Mineral Structure of the Earth,' and as a mark of esteem for one who, in an age of specialization, has, almost alone among geologists, contributed brilliant and original memoirs dealing with subjects appertaining to every branch of Geological Science.

The Murchison Medal, with a sum of Ten Guineas from the Murchison Geological Fund, is awarded to Mr. Richard Hill Tiddeman, in recognition of his valuable contributions to Geological Science, more especially in connexion with the Carboniferous and Pleistocene formations in Britain.

The Lyell Medal, together with a sum of Twenty-Five Pounds, is this year exceptionally awarded in duplicate, to

Dr. Francis Arthur Bather, in recognition of his contributions to our knowledge of the Palæontology of the Invertebrata, and especially of the Echinodermata; and to

Dr. Arthur Walton Rowe, as an acknowledgment of his contributions to our knowledge of the zonal sequence in the Upper Cretaceous rocks.

The Bigsby Medal is awarded to Prof. Othenio Abel, in recognition of his contributions to our knowledge of the Palæontology of the Vertebrata, more especially of the Cetacea and Sirenia, and to encourage him in further research.

The Balance of the Proceeds of the Wollaston Donation Fund is awarded to Prof. Owen Thomas Jones, as an acknowledgment of the value of his extensive researches among the Lower Palæozoic rocks of Wales.

The Balance of the Proceeds of the Murchison Geological Fund is awarded to Mr. Edgar Sterling Cobbold, in recognition of his investigations among the Lower Palæozoic rocks of Shropshire, whereby he has been enabled to establish the sequence of the three lowest Cambrian faunas in this country.

The Balance of the Proceeds of the Lyell Geological Fund is awarded to Dr. Charles Gilbert Cullis, in acknowledgment of his contributions to our knowledge of the Origin of Dolomites, and to stimulate him in further work.

A portion of the Proceeds of the Barlow-Jameson Fund is awarded to Mr. John Frederick Norman Green, as an acknowledgment of his work on the older rocks in the neighbourhood of St. David's, and to encourage him in further researches.

Report of the Library and Museum Committee for 1910.

The Committee have pleasure in reporting that the Additions made to the Society's Library during the past twelve months have fully maintained, both in number and in importance, the standard of previous years.

During the year 1910, the Library received by Donation 231 Volumes of separately published Works, 296 Pamphlets, 40 detached Parts of Works, also 327 Volumes and 24 detached Parts of Serial Publications, and 25 Volumes of Weekly Periodicals.

The total number of accessions to the Library by Donation is thus found to amount to 583 Volumes, 296 Pamphlets, and 64 detached Parts. Moreover, 176 Sheets of Geological Maps were presented to the Library, including 65 Sheets received from the Geological Survey of England and Wales, and 52 Sheets from that of Scotland; 3 Sheets of the International Geological Map of Europe; 12 Folios of the Geologic Atlas of the United States; 8 Sheets received from the Geological Survey of the State of Victoria; 7 Sheets from the Geological Survey of Egypt; 7 Sheets from the Geological Survey of Japan; 5 Sheets from the Swiss Geological Commission; and 5 Sheets from the Imperial Austrian Reichsanstalt.

Among the Books and Pamphlets mentioned in the preceding paragraph, especial attention may be directed to the following works:—The fourth Volume of Miss Hertha Sollas's translation ('The Face of the Earth') of Prof. E. Suess's 'Antlitz der Erde'; the sixth fasciculus of Dr. L. Carez's 'Geology of the French Pyrenees'; Dr. F. A. Bather's monograph on the Triassic Echinoderms of Bakony; twelve volumes published in commemoration of

the bi-centenary of Linnæus, presented by the University of Upsala; Dr. B. Lotti's 'Geology of Tuscany' (vol. xiii of the Memorie descrittive della Carta geologica d'Italia); the monograph on the Basin of the Upper Vishéra (Northern Urals), by Prof. L. Duparc and others; the monographs on the Fossil Fishes of Northern France and the neighbouring regions, and on the Oligocene Fishes of Belgium, by M. Leriche; Dr. F. H. Hatch's Report on the Mines & Mineral Resources of Natal; Mr. H. B. Woodward's 'Geology of Water-Supply'; Mr. L. L. Fermor's monograph on the Manganese Ore-Deposits of India; Dr. Ivor Thomas's monograph on the Carboniferous Orthotetinæ; the second volume of Prof. J. W. Gregory's British Museum Catalogue of the Cretaceous Bryozoa; Dr. C. W. Andrews's Descriptive Catalogue (British Museum) of the Marine Reptiles of the Oxford Clay; and six volumes of the Proceedings of the Dorset Natural History & Antiquarian Field-Club, presented through the Rev. J. C. M. Mansell-Pleydell. The Geological Survey Memoirs on the London District, on the Country around Bodmin & St. Austell, on the Country around Basingstoke and around Alresford, on the Melton Mowbray District, etc., on the Country around Nottingham, and on the Country around Carmarthen, were received; as also Dr. A. Strahan's 'Guide to the Geological Model of Ingleborough & District.' Moreover, numerous publications were received from the Geological Survey departments of the Cape Colony, the Transvaal, of the various States of the Australian Commonwealth, and of the Dominion of New Zealand; also from the Geological Survey departments of Egypt, India, Italy, Norway, Portugal, Prussia, Rumania, Russia, and Sweden; from the United States Geological Survey, and from the independent State Surveys of Illinois, Iowa, Kansas, Maryland, and New York.

The Books and Maps enumerated in the foregoing paragraphs were the gift of 151 Government Departments and other Public Bodies; of 180 Societies and Editors of Periodicals; and of 196 Personal Donors.

The Purchases, made on the recommendation of the standing Library Committee, included 61 Volumes and 7 detached Parts of separately published Works; 89 Volumes and 12 detached Parts of Works published serially; and 22 Sheets of Geological Maps.

The Expenditure incurred in connexion with the Library during the year under review was as follows:—

	£	*s.*	*d.*
Books, Periodicals, etc. purchased	107	17	5
Binding of Books and Mounting of Maps ..	149	14	8
	£257	12	1

Mr. C. Davies Sherborn reports that steady progress continues to be made with the preparation of the Card Catalogue of the Library.

MUSEUM.

For the purpose of study and comparison, the Society's Collections were visited on 22 occasions during the year, the contents of 74 drawers being thus examined. The permission of the Council having been duly obtained, some 32 specimens were lent in the course of 1910 to various investigators.

No expenditure has been incurred in connexion with the Museum during the past year.

The appended Lists contain the Names of Government Departments, Public Bodies, Societies, Editors, and Personal Donors, from whom Donations to the Library have been received during the year under review :—

I. GOVERNMENT DEPARTMENTS AND OTHER PUBLIC BODIES.

Alabama.—Geological Survey. Montgomery (Ala.).
American Museum of Natural History. New York.
Argentina.—Ministerio de Agricultura. Buenos Aires.
Australia (S.), etc. *See* South Australia, *etc.*
Austria.—Kaiserlich-Königliche Geologische Reichsanstalt. Vienna.
Bavaria.—Königliches Bayerisches Oberbergamt. Munich.
Belgium.—Académie Royale des Sciences, des Lettres & Beaux-Arts de Belgique, Brussels.
——. Musée Royal d'Histoire Naturelle. Brussels.
——. Service géologique de Belgique. Brussels.
Bergens Museum. Bergen.
Berlin.—Königliche Preussische Akademie der Wissenschaften.
Birmingham, University of.
Bohemia.—Naturwissenschaftliche Landesdurchforschung. Prague.
——. Royal Museum of Natural History. Prague.
Bristol.—Public Library.
British Columbia.—Department of Mines. Victoria (B.C.).
British Guiana.—Department of Mines. Georgetown.
British South Africa Company. London.
Buenos Aires.—Museo Nacional de Buenos Aires.
California.—Academy of Sciences. San Francisco.
——, University of. Berkeley (Cal.).
Camborne.—Mining School.
Cambridge (Mass.).—Museum of Comparative Zoology in Harvard College.
Canada.—Geological & Natural History Survey. Ottawa.
——, High Commissioner for. London.
Cape Colony.—Department of Agriculture (Geological Commission). Cape Town.
——. South African Museum. Cape Town.
Chicago.—'Field' Columbian Museum.
Connecticut.—State Geological & Natural History Survey. Hartford (Conn.).
Córdoba (Argentine Republic).—Academía Nacional de Ciencias.
Cracow.—Academy of Sciences.
Denmark.—Commission for Ledelsen af de Geologiske & Geographiske Undersögelser i Grönland. Copenhagen.
——. Geologiske Undersögelse. Copenhagen.
——. Kongelige Danske Videnskabernes Selskab. Copenhagen.
Dublin.—Royal Irish Academy.
Egypt.—Department of Public Works (Survey Department). Cairo.
Finland.—Finlands Geologiska Undersökning. Helsingfors.
France.—Ministère de la Guerre. Paris.

France.—Ministère des Colonies. Paris.
——. Ministère des Travaux Publics. Paris.
——. Muséum d'Histoire Naturelle. Paris.
Georgia.—Geological Survey. Atlanta (Ga.).
Germany.—Kaiserliche Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher. Halle an der Saale.
Great Britain.—Army Medical Department. London.
——. British Museum (Natural History). London.
——. Colonial Office. London.
——. Geological Survey. London.
——. Home Office. London.
——. India Office. London.
Holland.—Departement van Kolonien. The Hague.
——. Staatliche Bohrverwaltung in den Niederlanden. The Hague.
Hull.—Municipal Museum.
Hungary.—Königliche Ungarische Geologische Anstalt (Magyar Földtani Tarsulat). Budapest.
Illinois State Museum of Natural History. Springfield (Ill.).
India.—Geological Survey. Calcutta.
——. Indian Museum. Calcutta.
——. Surveyor-General's Office. Calcutta.
Iowa Geological Survey. Des Moines (Iowa).
Ireland.—Department of Agriculture & Technical Instruction. Dublin.
Italy.—Reale Comitato Geologico. Rome.
Japan.—Earthquake-Investigation Committee. Tokio.
——. Geological Survey. Tokio.
Jassy, University of.
Kansas.—University Geological Survey. Lawrence (Kan.).
Kingston (Canada).—Queen's College.
Klausenburg (Koloszvár).—Provincial Museum & Library.
Leeds, University of.
London.—City of London College.
——. Imperial College of Science & Technology.
——. Imperial Institute.
——. Royal College of Surgeons.
——. University College.
Madrid.—Real Academía de Ciencias Exactes, Físicas & Naturales.
Magdeburg.—Museum für Natur- und Heimatkunde.
Maryland.—Geological Survey. Baltimore (Md.).
Melbourne (Victoria).—National Museum.
Mexico.—Instituto Geológico. Mexico City.
Michigan College of Mines. Houghton (Mich.).
Milan.—Reale Istituto Lombardo di Scienze & Lettere.
Missouri.—Bureau of Geology & Mines. Jefferson City (Mo.).
Montana University. Missoula (Mont.).
Munich.—Königliche Bayerische Akademie der Wissenschaften.
Mysore Geological Department. Bangalore.
Nancy.—Académie de Stanislas.
Naples.—Accademia delle Scienze.
Natal.—Department of Mines. Pietermaritzburg.
——. Geological Survey. Pietermaritzburg.
——. Government Museum. Pietermaritzburg.
Newcastle-upon-Tyne.—Armstrong College.
New Jersey.—Geological Survey. Trentham (N.J.).
New South Wales, Agent-General for. London.
——. Department of Mines & Agriculture. Sydney.
——. Geological Survey. Sydney.
New York State Museum. Albany (N.Y.).
New Zealand.—Department of Mines. Wellington.
——. Geological Survey. Wellington.
Norway.—Norges Geologiske Undersökelse. Christiania.
Nova Scotia.—Department of Mines. Halifax.
Ohio Geological Survey. Columbus (Ohio).
Ontario.—Bureau of Mines. Toronto.
Padua.—Reale Accademia di Scienze, Lettere & Arti.
Paris.—Académie des Sciences.
Perak Government. Taiping.
Peru.—Ministerio de Fomento. Lima.

Philippine Is.—Department of the Interior; Bureau of Science. Manila.
Pisa, Royal University of.
Portugal.—Commissão dos Trabalhos Geologicos. Lisbon.
Prussia.—Königliches Ministerium für Handel & Gewerbe. Berlin.
——. Königliche Preussische Geologische Landesanstalt. Berlin.
Queensland, Agent-General for. London.
——. Department of Mines. Brisbane.
——. Geological Survey. Brisbane.
Redruth.—School of Mines.
Rhodesia.—Chamber of Mines. Bulawayo.
Rhodesian Museum. Bulawayo.
Rio de Janeiro.—Museu Nacional.
Rome.—Reale Accademia dei Lincei.
Rumania.—Geological Survey. Bucarest.
Russia.—Comité Géologique. St. Petersburg.
——. Musée Géologique Pierre le Grand. St. Petersburg.
——. Section Géologique du Cabinet de S.M. l'Empereur. St. Petersburg.
São Paulo (Brazil).—Commissão Geographica & Geologica. São Paulo City.
——. Secretaria da Agricultura, Commercio & Obras Publicas. São Paulo City.
South Australia, Agent-General for. London.
——. Department of Mines. Adelaide.
——. Geological Survey. Adelaide.
Spain.—Comision del Mapa Geológico. Madrid.
Stockholm.—Kongliga Svenska Vetenskaps Akademi.
Sweden.—Sveriges Geologiska Undersökning. Stockholm.
Switzerland.—Geologische Kommission der Schweiz. Berne.
Tasmania.—Secretary for Mines. Hobart.
Tokio.—Imperial University.
——. College of Science.
Transvaal.—Geological Survey. Pretoria.
——. Mines Department. Pretoria.
Turin.—Reale Accademia delle Scienze.
United States.—Department of Agriculture. Washington (D.C.).
——. Geological Survey. Washington (D.C.).
——. National Museum. Washington (D.C.).
Upsala, Royal University of.
Victoria (Austral.), Agent-General for. London.
—— (——). Department of Mines. Melbourne.
—— (——). Geological Survey. Melbourne.
Vienna.—Kaiserliche Akademie der Wissenschaften.
Washington (D.C.).—Smithsonian Institution.
Washington, State of (U.S.A.).—Geological Survey. Olympia (Wash.).
West Indies.—Imperial Agricultural Department. Bridgetown (Barbados).
Western Australia, Agent-General for. London.
——. Department of Mines. Perth.
——. Geological Survey. Perth.
Wisconsin.—Geological & Natural History Survey. Madison (Wisc.).
Yale University Museum (Peabody Museum). Geological Department. New Haven (Conn.).

II. Societies and Editors.

Acireale.—Accademia di Scienze, Lettere & Arti.
Adelaide.—Royal Society of South Australia.
Agram.—Societas Historico-Naturalis Croatica.
Alnwick.—Berwickshire Naturalists' Club.
Basel.—Naturforschende Gesellschaft.
Bath.—Natural History & Antiquarian Field-Club.
Belgrade.—Servian Geological Society.
Bergen.—'Naturen.'
Berlin.—Deutsche Geologische Gesellschaft.
——. Gesellschaft Naturforschender Freunde.
——. 'Zeitschrift für Praktische Geologie.'
Berne.—Schweizerische Naturforschende Gesellschaft.
Bombay Branch of the Royal Asiatic Society.
Bordeaux.—Société Linnéenne.

Boston (Mass.) Society of Natural History.
——. American Academy of Arts & Sciences.
Bristol Naturalists' Society.
Brooklyn (N.Y.) Institute of Arts & Sciences.
Brunswick.—Verein für Naturwissenschaft zu Braunschweig.
Brussels.—Société Belge de Géologie, de Paléontologie & d'Hydrologie.
——. Société Royale Zoologique & Malacologique de Belgique.
Budapest.—Földtani Közlöny.
Buenos Aires.—Sociedad Científica Argentina.
Bulawayo.—Rhodesian Scientific Association.
Caen.—Société Linnéenne de Normandie.
Calcutta.—Asiatic Society of Bengal.
——. 'Indian Engineering.'
Cambridge Philosophical Society.
Cape Town.—South African Association for the Advancement of Science.
——. South African Philosophical Society.
Cardiff.—South Wales Institute of Engineers.
Chambéry.—Société d'Histoire Naturelle de Savoie.
Chicago.—'Journal of Geology.'
Christiania.—Norsk Geologisk Forening.
——. 'Nyt Magazin for Naturvidenskaberne.'
Colombo.—Ceylon Branch of the Royal Asiatic Society.
Colorado Springs.—'Colorado College Studies.'
Croydon Natural History & Scientific Society.
Denver.—Colorado Scientific Society.
Dijon.—Académie des Sciences, Arts & Belles-Lettres.
Dorpat (Jurjew).—Naturforschende Gesellschaft.
Dresden.—Naturwissenschaftliche Gesellschaft.
——. Verein für Erdkunde.
Edinburgh.—Geological Society.
——. Royal Scottish Geographical Society.
——. Royal Society.
Ekaterinburg.—Société Ouralienne d'Amateurs des Sciences Naturelles.
Falmouth.—Royal Cornwall Polytechnic Society.
Frankfurt am Main.—Senckenbergische Naturforschende Gesellschaft.
Freiburg im Breisgau.—Naturforschende Gesellschaft.
Fribourg.—Société Fribourgeoise des Sciences Naturelles.
Geneva.—Société de Physique & d'Histoire Naturelle.
Giessen.—Oberhessische Gesellschaft für Natur- & Heilkunde.
Glasgow.—Geological Society.
Gloucester.—Cotteswold Naturalists' Field-Club.
Gratz.—Naturwissenschaftlicher Verein für Steiermark.
Haarlem.—Société Hollandaise des Sciences.
Halifax (N.S.).—Nova Scotian Institute of Science.
Hamilton (Canada).—Hamilton Scientific Association.
Hanau.—Wetterauische Gesellschaft für Gesammte Naturkunde.
Havre.—Société Géologique de Normandie.
Helsingfors.—Société Géographique de Finlande.
Hereford.—Woolhope Naturalists' Field-Club.
Hermannstadt.—Siebenbürgischer Verein für Naturwissenschaft.
Hertford.—Hertfordshire Natural History Society.
Hull Geological Society.
Indianapolis (Ind.).—Indiana Academy of Science.
Johannesburg.—Geological Society of South Africa.
Kiev.—Société des Naturalistes.
Lancaster (Pa.).—'Economic Geology.'
Lausanne.—Société Vaudoise des Sciences Naturelles.
Lawrence (Kan.).—'Kansas University Bulletin.'
Leeds.—Geological Association.
——. Philosophical & Literary Society.
——. Yorkshire Geological Society.
Leicester Literary & Philosophical Society.
Leipzig.—'Zeitschrift für Krystallographie & Mineralogie.
Liége.—Société Géologique de Belgique.
——. Société Royale des Sciences.
Lille.—Société Géologique du Nord.
Lima.—'Revista de Ciencias.'
Lisbon.—Sociedade de Geographia.

Lisbon.—Société Portugaise des Sciences Naturelles.
Liverpool Geological Society.
——. Literary & Philosophical Society.
London.—Association of Water Engineers.
——. 'The Athenæum.'
——. British Association for the Advancement of Science.
——. Chemical Society.
——. 'The Chemical News.'
——. 'The Colliery Guardian.'
——. 'The Geological Magazine.'
——. Geologists' Association.
——. Institution of Civil Engineers.
——. Institution of Mining Engineers.
——. Institution of Mining & Metallurgy.
——. Iron & Steel Institute.
——. Linnean Society.
——. 'The London, Edinburgh, & Dublin Philosophical Magazine.'
——. Mineralogical Society.
——. 'The Mining Journal.'
——. 'Nature.'
——. Palæontographical Society.
——. 'The Quarry.'
——. Ray Society.
——. 'Records of the London & West-Country Chamber of Mines.'
——. Royal Geographical Society.
——. Royal Institution.
——. Royal Meteorological Society.
——. Royal Microscopical Society.
——. Royal Photographic Society.
——. Royal Society.
——. Royal Society of Arts.
——. Society of Biblical Archæology.
——. 'The South-Eastern Naturalist' (S.E. Union of Scientific Societies).
——. Victoria Institute.
——. 'Water.'
——. Zoological Society.
Manchester Geological & Mining Society.
——. Literary & Philosophical Society.
Manila.—Philippine Journal of Science.
Melbourne (Victoria).—Australasian Institute of Mining Engineers.
——. Royal Society of Victoria.
——. 'The Victorian Naturalist.'
Mexico.—Sociedad Científica 'Antonio Alzate.'
Moscow.—Société Impériale des Naturalistes.
New Haven (Conn.).—'The American Journal of Science.
New York.—Academy of Sciences.
——. American Institute of Mining Engineers.
——. 'Science.'
Newcastle-upon-Tyne.—North of England Institute of Mining & Mechanical Engineers.
——. University of Durham Philosophical Society.
Northampton.—Northamptonshire Natural History Society.
Nürnberg.—Naturhistorische Gesellschaft.
Oporto.—Academia Polytecnica. [Coimbra.]
Ottawa.—Royal Society of Canada.
Paris.—Commission Française des Glaciers.
——. Société Française de Minéralogie.
——. Société Géologique de France.
——. 'Spelunca.'
Penzance.—Royal Geological Society of Cornwall.
Perth.—Perthshire Society of Natural Science.
Philadelphia.—Academy of Natural Sciences.
——. American Philosophical Society.
Pisa.—Società Toscana di Scienze Naturali.
Plymouth.—Devonshire Association for the Advancement of Science.
Rennes.—Société Scientifique & Médicale de l'Ouest.
Rochester (N.Y.).—Academy of Science.
——. Geological Society of America.

Rome.—Società Geologica Italiana.
Rugby School Natural History Society.
Santiago de Chile.—Sociedad Nacional de Minería.
——. Société Scientifique du Chili.
São Paulo (Brazil).—Sociedade Scientifica.
Scranton (Pa.).—'Mines & Minerals.'
St. John (N.B.).—Natural History Society of New Brunswick.
St. Petersburg.—Russische Kaiserliche Mineralogische Gesellschaft.
Stockholm.—Geologiska Förening.
Stratford.—Essex Field-Club.
Stuttgart.—'Centralblatt für Mineralogie, Geologie & Paläontologie.'
——. 'Neues Jahrbuch für Mineralogie, Geologie & Paläontologie.'
——. Oberrheinischer Geologischer Verein.
——. Verein für Vaterländische Naturkunde in Württemberg.
——. 'Zeitschrift für Naturwissenschaften.'
Sydney (N.S.W.).—Linnean Society of New South Wales.
——. Royal Society of New South Wales.
Toronto.—Canadian Institute.
Toulouse.—Société d'Histoire Naturelle.
Truro.—Royal Institution of Cornwall.
Vienna.—'Beiträge zur Paläontologie & Geologie Œsterreich-Ungarns & des Orients.'
——. 'Berg- & Hüttenmännisches Jahrbuch.'
——. Geologische Gesellschaft.
——. Kaiserlich-Königliche Zoologisch-Botanische Gesellschaft.
Washington (D.C.).—Academy of Sciences.
——. Biological Society.
——. Philosophical Society.
Wellington (N.Z.).—New Zealand Institute.
Wiesbaden.—Nassauischer Verein für Naturkunde.
Worcester.—Worcestershire Naturalists' Club.
York.—Yorkshire Philosophical Society.

III. Personal Donors.

Adams, F. D.
Adams, J.
Ameghino, F.
Andrew, A. R.
Andrews, E. C.
Andrusov, N.
Arctowski, H.
Armitage, R. W.
Arnold, E.
Arnold-Bemrose, H. H.
Arsandaux, H.

Bailey, T. E. G.
Basedow, H.
Bather, F. A.
Bennett, F. J.
Bœhm, G.
Boyle, R.
Branca, W.
Branner, J. C.
Breton, L.
Bullen, Rev. R. A.
Burr, A.

Cameron, A. C. G.
Carez, L.
Carus-Wilson, C.
Chandler, R. H.
Chapman, F.
Charcot, —.
Choffat, P.
Christy, M.
Clinch, G.
Clough, C. T.
Cockayne, L.
Coker, E. G.
Cole, G. A. J.
Collingridge, W.
Collins, J. H.
Cooper, L.
Crampton, C. B.
Crick, G. C.
Cumings, E. R.

Dall, W. H.
Dalton, L. V.
Daly, R. A.
Davison, C.
Dewey, H.
Dionne, N. E.
Drygalski, E. von.
Dunn, E. J.
Duparc, L.

Egglestone, W. M.
Ellis, T. S.
Evans, J. W.

Fearnsides, W. G.
Ferrar, H. T.
Filliozat, M.
Finlayson, A. M.
Flett, J. S.
Foote, W. M.
Forel, F. A.
Fritsch, A.

Garwood, E. J.
Geikie, Sir Archibald.
Gerth, H.
Ghose, A.
Gibson, W.
Gordon, Mrs. M. O.
Grayson, J. H.
Gregory, J. W.
Grosch, P.

Habershon, M. H.
Hardwick, F. W.
Harmer, F. W.
Hatch, F. H.
Heim, A.
Hill, H.
Hind, W.
Hobson, B.
Hopkinson, J.
Horwood, A. R.
Horwood, C. B.
Hovenden, F.
Hovey, E. O.
Huggins, Sir William.
Hull, E.
Hume, W. F.

Hume, W. H.
Hutchinson, Rev. H. N.

Issel, A.

Jackson, J. W.
Jentzsch, A.
Jentzsch, J.
Johnson, D. W.
Johnson, T.
Jordan, H. K.
Jutson, J. T.

Kennard, A. S.
Kidner, H.
Kœnen, A. von.
Krishtafovich, N. F.
Kronecker, W.

Lacroix, A.
Lamb, G. F.
Lambe, L. M.
Landes, H.
Lang, A.
Lemoine, P.
Lenicque, H.
Leriche, M.
Liebisch, T.
Louderback, G. D.
Lowerison, B.

Maitland, A. G.
Margerie, E. de.
Marr, J. E.
Martin, E. A.
Martin, L.
Maslen, A. J.
Maufe, H. B.
Mennell, F. P.
Merzbacher, G.
Monckton, H. W.
Moreno, F. P.

Nathorst, A. G.
Newton, E. T.

Ord, W. T.
Oswald, F.

Park, Mongo.
Pavlov, (Mdme.) M. V.
Perceval, S. G.
Petterd, W. F.
Plotts, W.
Pogue, J. E.
Pollard, W.
Porto, A.
Pringle, J.
Prosser, C. S.
Purdue, A. H.

Radley, E. G.
Reed, F. R. C.
Reid, C.
Reid, Mrs. E. M.
Ricciardi, L.
Richards, H. C.
Richardson, L.

Sabot, R.
Sauvage, H. E.
Scharff, R. S.
Schmidt, M.
Schmidt, R. R.
Schwarz, E. H. L.
Scott, D. H.
Seward, A. C.
Sheppard, T.
Sjögren, H.
Skeats, E. W.
Smith, S.
Smith, W. D.
Sollas, W. J.
Speight, R.
Spencer, J. W.
Steinmann, G.
Stevenson, J. J.
Suess, E.
Summers, R. S.

Tait, D.
Tarr, R. S.
Termier, P.
Thompson, B.
Thomson, J. A.
Thoroddsen, T.
Thresh, M.
Tilho, J.
Tœrnquist, S. L.

Waagen, L.
Wade, A.
Wadsworth, M. E.
Ward, L. K.
Warren, H.
Washington, H. S.
Wernert, P.
Whitaker, W.
White, H. J. O.
Wieland, G. R.
Wilckens, O.
Wilde, H.
Willis, B.
Williston, S. W.
Winwood, Rev. H. H.
Wolff, W.
Woodward, A. S.
Woodward, Henry.
Woodward, H. B.
Wright, F. E.
Wunder, M.

Zeiller, R.

COMPARATIVE STATEMENT OF THE NUMBER OF THE SOCIETY AT THE CLOSE OF THE YEARS 1909 AND 1910.

	Dec. 31st, 1909.	Dec. 31st, 1910.
Compounders	258	252
Contributing Fellows	1011	1025
Non-Contributing Fellows	25	22
	1294	1299
Foreign Members	40	40
Foreign Correspondents	38	40
	1372	1379

Comparative Statement, explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the years 1909 and 1910.

Number of Compounders, Contributing and Non-Contributing Fellows, December 31st, 1909		1294
Add Fellows elected during the former year and paid in 1910		21
Add Fellows elected and paid in 1910		35
		1350
Deduct Compounders deceased	8	
Contributing Fellows deceased	13	
Non-Contributing Fellows deceased	3	
Contributing Fellows resigned	18	
Contributing Fellows removed	9	
		51
		1299
Number of Foreign Members and Foreign Correspondents, December 31st, 1909	78	
Add Foreign Correspondents elected	2	
		80
		1379

Deceased Fellows.

Compounders (8).

- Blake, Prof. W. P.
- Heaphy, T. M.
- Shelley, Capt. G. E.
- Smethurst, W.
- Smith, C.
- Tendron, F.
- Watson, Rev. Dr. R. B.
- Whidborne, Rev. G. F.

Resident and other Contributing Fellows (13).

- Bird, C.
- Brown, A.
- Clark, J. F.
- Cooke, Dr. T.
- Cross, E.
- Evans, Rev. de C.
- Fox-Strangways, C.
- Godson, G. R.
- Klaassen, H. M.
- Llewellin, W. M.
- Melliss, J. C.
- Stokes, A. H.
- Young, J. T.

Non-Contributing Fellows (3).

- Egerton, Prebendary W. H.
- Prout, Rev. J. T.
- Warrand, Maj.-Gen. W. G.

Fellows Resigned (18).

- Alford, C. J.
- Baker, F.
- Burton, W. J. P.
- Du Pre, F. B.
- Finch, A. L.
- Geikie, W. H. C.
- Hermitage, H. F.
- Hilgendorf, F. W.
- Humble, W.
- Jones, D.
- Middleton, F. E.
- Mitcheson, G. A.
- Murdock, J. V. B.
- Penton, E.
- Quilliam, W. H. A.
- Rau, H. N.
- Wilkins, C.
- Wilson, C. J.

Fellows Removed (9).

- Buddicom, R. A.
- Butler, C. A. V.
- Chenhall, J. W.
- Davies, T. H.
- Gooch, A. E.
- Hampson, B. A.
- Hawkins, J. T.
- Hiorns, A., jun.
- Lines, E.

The following Personages were elected Foreign Correspondents during the year 1910:—

Prof. François Alphonse Forel, of Lausanne.
Dr. A. E. Törnebohm, of Stockholm.

After the Reports had been read, it was resolved:—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and circulated among the Fellows.

It was afterwards resolved:—

That the thanks of the Society be given to Mr. H. W. Monckton (also retiring from the Council), retiring from the office of Vice-President.

That the thanks of the Society be given to Dr. F. L. Kitchin, Mr. H. Woods, Mr. H. B. Woodward, and Mr. G. W. Young, retiring from the Council.

After the Balloting-Glasses had been closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year:—

OFFICERS AND COUNCIL.—1911.

PRESIDENT.

Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.

VICE-PRESIDENTS.

Charles William Andrews, B.A., D.Sc., F.R.S.
Alfred Harker, M.A., F.R.S.
John Edward Marr, Sc.D., F.R.S.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.

SECRETARIES.

Prof. Edmund Johnston Garwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

FOREIGN SECRETARY.

Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.

TREASURER.

Aubrey Strahan, Sc.D., F.R.S.

COUNCIL.

Henry A. Allen.
Tempest Anderson, M.D., D.Sc.
Charles William Andrews, B.A., D.Sc., F.R.S.
Henry Howe Arnold-Bemrose, J.P., Sc.D.
George Barrow.
Prof. Thomas George Bonney, Sc.D., LL.D., F.R.S.
Prof. William S. Boulton, B.Sc.
James Vincent Elsden, D.Sc.
John Smith Flett, M.A., D.Sc.
Prof. Edmund J. Garwood, M.A.
Sir Archibald Geikie, K.C.B., D.C.L., LL.D., Sc.D., Pres.R.S.
Alfred Harker, M.A., F.R.S.
Robert Stansfield Herries, M.A.
Bedford McNeill, Assoc.R.S.M.
John Edward Marr, Sc.D., F.R.S.
George Thurland Prior, M.A., D.Sc.
Prof. Sidney Hugh Reynolds, M.A.
Prof. William Johnson Sollas, LL.D., Sc.D., F.R.S.
Aubrey Strahan, Sc.D., F.R.S.
Herbert Henry Thomas, M.A., B.Sc.
Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.
Rev. Henry Hoyte Winwood, M.A.
Arthur Smith Woodward, LL.D., F.R.S., F.L.S.

LIST OF

THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1910.

Date of Election.	
1877.	Prof. Eduard Suess, *Vienna.*
1880.	Geheimrath Prof. Ferdinand Zirkel, *Leipzig.*
1884.	Commendatore Prof. Giovanni Capellini, *Bologna.*
1885.	Prof. Jules Gosselet, *Lille.*
1886.	Prof. Gustav Tschermak, *Vienna.*
1890.	Geheimrath Prof. Heinrich Rosenbusch, *Heidelberg.*
1891.	Prof. Charles Barrois, *Lille.*
1893.	Prof. Waldemar Christofer Brögger, *Christiania.*
1893.	M. Auguste Michel-Lévy, *Paris.*
1893.	Prof. Alfred Gabriel Nathorst, *Stockholm.*
1894.	Prof. George J. Brush, *New Haven, Conn.* (*U.S.A.*).
1894.	Prof. Edward Salisbury Dana, *New Haven, Conn.* (*U.S.A.*).
1895.	Dr. Grove Karl Gilbert, *Washington, D.C.* (*U.S.A.*).
1896.	Prof. Albert Heim, *Zürich.*
1897.	M. Édouard Dupont, *Brussels.* (*Deceased.*)
1897.	Dr. Anton Fritsch, *Prague.*
1897.	Dr. Hans Reusch, *Christiania.*
1898.	Geheimrath Prof. Hermann Credner, *Leipzig.*
1898.	Dr. Charles Doolittle Walcott, *Washington, D.C.* (*U.S.A.*).
1899.	Prof. Emanuel Kayser, *Marburg.*
1899.	M. Ernest Van den Broeck, *Brussels.*
1899.	Dr. Charles Abiathar White, *Washington, D.C.* (*U.S.A.*).
1900.	M. Gustave F. Dollfus, *Paris.*
1900.	Prof. Paul von Groth, *Munich.*
1900.	Dr. Sven Leonhard Törnquist, *Lund.*
1901.	M. Alexander Petrovich Karpinsky, *St. Petersburg.*
1901.	Prof. Alfred Lacroix, *Paris.*
1903.	Prof. Albrecht Penck, *Berlin.*
1903.	Prof. Anton Koch, *Budapest.*
1904.	Prof. Joseph Paxson Iddings, *Chicago* (*U.S.A.*).
1904.	Prof. Henry Fairfield Osborn, *New York* (*U.S.A.*).
1905.	Prof. Louis Dollo, *Brussels.*
1905.	Prof. August Rothpletz, *Munich.*
1906.	Prof. Count Hermann zu Solms-Laubach, *Strasburg.*
1907.	Hofrath Dr. Emil Ernst August Tietze, *Vienna.*
1907.	Commendatore Prof. Arturo Issel, *Genoa.*
1908.	Prof. Bundjirô Kôtô, *Tokyo.*
1908.	Dr. Feodor Černyšev, *St. Petersburg.*
1909.	Prof. Johan H. L. Vogt, *Christiania.*
1909.	Prof. René Zeiller, *Paris.*

LIST OF
THE FOREIGN CORRESPONDENTS
OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1910.

Date of Election.	
1874.	Prof. Igino Cocchi, *Florence.*
1879.	Dr. H. Émile Sauvage, *Boulogne-sur-Mer.*
1889.	Dr. Rogier Diederik Marius Verbeek, *The Hague.*
1890.	Geheimer Bergrath Prof. Adolph von Kœnen, *Göttingen.*
1892.	Prof. Johann Lehmann, *Kiel.*
1893.	Prof. Aléxis P. Pavlow, *Moscow.*
1893.	M. Ed. Rigaux, *Boulogne-sur-Mer.*
1894.	Dr. Francisco P. Moreno, *La Plata.*
1895.	Prof. Constantin de Kroustchoff, *St. Petersburg.*
1896.	Prof. Johannes Walther, *Halle an der Saale.*
1897.	M. Emmanuel de Margerie, *Paris.*
1898.	Dr. Marcellin Boule, *Paris.*
1898.	Dr. W. H. Dall, *Washington, D.C.* (*U.S.A.*).
1899.	Dr. Gerhard Holm, *Stockholm.*
1899.	Prof. Theodor Liebisch, *Göttingen.*
1899.	Prof. Franz Lœwinson-Lessing, *St. Petersburg.*
1899.	M. Michel F. Mourlon, *Brussels.*
1899.	Prof. Gregorio Stefanescu, *Bucarest.* (*Deceased.*)
1900.	Prof. Ernst Koken, *Tübingen.*
1900.	Prof. Federico Sacco, *Turin.*
1901.	Prof. Friedrich Johann Becke, *Vienna.*
1902.	Prof. Thomas Chrowder Chamberlin, *Chicago, Ill.* (*U.S.A.*).
1902.	Dr. Thorvaldr Thoroddsen, *Copenhagen.*
1902.	Prof. Samuel Wendell Williston, *Chicago, Ill.* (*U.S.A.*).
1904.	Dr. William Bullock Clark, *Baltimore* (*U.S.A.*).
1904.	Dr. Erich Dagobert von Drygalski, *Charlottenburg.*
1904.	Prof. Giuseppe de Lorenzo, *Naples.*
1904.	The Hon. Frank Springer, *Burlington, Iowa* (*U.S.A.*).
1904.	Dr. Henry S. Washington, *Locust, N.J.* (*U.S.A.*).
1906.	Prof. John M. Clarke, *Albany, N.Y.* (*U.S.A.*).
1906.	Prof. William Morris Davis, *Cambridge, Mass.* (*U.S.A.*).
1906.	Dr. Jakob Johannes Sederholm, *Helsingfors.*
1907.	Prof. Baron Gerard Jakob de Geer, *Stockholm.*
1907.	Prof. Armin Baltzer, *Berne.*
1908.	Prof. Hans Schardt, *Veytaux, near Montreux.*
1909.	Dr. Daniel de Cortázar, *Madrid.*
1909.	Prof. Maurice Lugeon, *Lausanne.*
1909.	Prof. Ralph S. Tarr, *Ithaca, N.Y.* (*U.S.A.*).
1910.	Prof. François Alphonse Forel. *Lausanne.*
1910.	Dr. A. E. Törnebohm. *Strengnös.*

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE 'DONATION FUND'

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., ETC.

'To promote researches concerning the mineral structure of the Earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,'—'such individual not being a Member of the Council.'

1831. Mr. William Smith.
1835. Dr. Gideon A. Mantell.
1836. M. Louis Agassiz.
1837. Capt. T. P. Cautley.
Dr. Hugh Falconer.
1838. Sir Richard Owen.
1839. Prof. C. G. Ehrenberg.
1840. Prof. A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron Leopold von Buch.
1843. M. Élie de Beaumont.
M. P. A. Dufrénoy.
1844. The Rev. W. D. Conybeare.
1845. Prof. John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. The Very Rev. W. Buckland.
1849. Sir Joseph Prestwich.
1850. Mr. William Hopkins.
1851. The Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. M. le Vicomte A. d'Archiac.
M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir Henry De la Beche.
1856. Sir William Logan.
1857. M. Joachim Barrande.
1858. Herr Hermann von Meyer.
Prof. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Prof. Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Prof. Gustav Bischof.
1864. Sir Roderick Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Prof. Carl F. Naumann.
1869. Dr. Henry C. Sorby.
1870. Prof. G. P. Deshayes.
1871. Sir Andrew Ramsay.
1872. Prof. James D. Dana.
1873. Sir P. de M. Grey Egerton.
1874. Prof. Oswald Heer.
1875. Prof. L. G. de Koninck.
1876. Prof. Thomas H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Prof. Bernhard Studer.
1880. Prof. Auguste Daubrée.
1881. Prof. P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Dr. William Thomas Blanford.
1884. Prof. Albert Jean Gaudry.
1885. Mr. George Busk.
1886. Prof. A. L. O. Des Cloizeaux.
1887. Mr. John Whitaker Hulke.
1888. Mr. Henry B. Medlicott.
1889. Prof. Thomas George Bonney.
1890. Prof. W. C. Williamson.
1891. Prof. John Wesley Judd.
1892. Baron F. von Richthofen.
1893. Prof. Nevil Story Maskelyne.
1894. Prof. Karl Alfred von Zittel.
1895. Sir Archibald Geikie.
1896. Prof. Eduard Suess.
1897. Mr. Wilfrid H. Hudleston.
1898. Prof. Ferdinand Zirkel.
1899. Prof. Charles Lapworth.
1900. Dr. Grove Karl Gilbert.
1901. Prof. Charles Barrois.
1902. Dr. Friedrich Schmidt.
1903. Prof. Heinrich Rosenbusch.
1904. Prof. Albert Heim.
1905. Dr. J. J. Harris Teall.
1906. Dr. Henry Woodward.
1907. Prof. William J. Sollas.
1908. Prof. Paul von Groth.
1909. Mr. Horace B. Woodward.
1910. Prof. William Berryman Scott.
1911. Prof. Waldemar Christofer Brögger.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON 'DONATION FUND.'

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. Gideon A. Mantell.
1836. Prof. G. P. Deshayes.
1838. Sir Richard Owen.
1839. Prof. C. G. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Prof. Edward Forbes.
1842. Prof. John Morris.
1843. Prof. John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. Cape of Good Hope Fossils.
M. Alcide d'Orbigny.
1849. Mr. William Lonsdale.
1850. Prof. John Morris.
1851. M. Joachim Barrande.
1852. Prof. John Morris.
1853. Prof. L. G. de Koninck.
1854. Dr. Samuel P. Woodward.
1855. Dr. G. Sandberger.
Dr. F. Sandberger.
1856. Prof. G. P. Deshayes.
1857. Dr. Samuel P. Woodward.
1858. Prof. James Hall.
1859. Mr. Charles Peach.
1860. Prof. T. Rupert Jones.
Mr. W. K. Parker.
1861. Prof. Auguste Daubrée.
1862. Prof. Oswald Heer.
1863. Prof. Ferdinand Senft.
1864. Prof. G. P. Deshayes.
1865. Mr. J. W. Salter.
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Dr. William Carruthers.
1870. M. Marie Rouault.
1871. Mr. Robert Etheridge.
1872. Dr. James Croll.
1873. Prof. John Wesley Judd.
1874. Dr. Henri Nyst.
1875. Prof. Louis C. Miall.
1876. Prof. Giuseppe Seguenza.
1877. Mr. Robert Etheridge, jun.
1878. Prof. William J. Sollas.
1879. Mr. Samuel Allport.
1880. Mr. Thomas Davies.
1881. Dr. Ramsay H. Traquair.
1882. Dr. George Jennings Hinde.
1883. Prof. John Milne.
1884. Mr. Edwin Tulley Newton.
1885. Dr. Charles Callaway.
1886. Mr. J. Starkie Gardner.
1887. Dr. Benjamin Neeve Peach.
1888. Dr. John Horne.
1889. Dr. A. Smith Woodward.
1890. Mr. William A. E. Ussher.
1891. Mr. Richard Lydekker.
1892. Mr. Orville Adelbert Derby.
1893. Mr. John George Goodchild.
1894. Dr. Aubrey Strahan.
1895. Prof. William W. Watts.
1896. Mr. Alfred Harker.
1897. Dr. Francis Arthur Bather.
1898. Prof. Edmund J. Garwood.
1899. Prof. John B. Harrison.
1900. Dr. George Thurland Prior.
1901. Mr. Arthur Walton Rowe.
1902. Mr. Leonard James Spencer.
1903. Mr. L. L. Belinfante.
1904. Miss Ethel M. R. Wood.
1905. Dr. H. H. Arnold-Bemrose.
1906. Dr. Finlay Lorimer Kitchin.
1907. Dr. Arthur Vaughan.
1908. Mr. Herbert Henry Thomas.
1909. Mr. Arthur J. C. Molyneux.
1910. Mr. Edward B. Bailey.
1911. Prof. Owen Thomas Jones.

AWARDS OF THE MURCHISON MEDAL

UNDER THE CONDITIONS OF THE

'MURCHISON GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, Bart., F.R.S., F.G.S.

'To be applied in every consecutive year, in such manner as the Council of the Society may deem most useful in advancing Geological Science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any enquiries bearing upon the science of Geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of Geological Science.'

1873. Mr. William Davies.
1874. Dr. J. J. Bigsby.
1875. Mr. W. J. Henwood.
1876. Mr. Alfred R. C. Selwyn.
1877. The Rev. W. B. Clarke.
1878. Prof. Hanns Bruno Geinitz.
1879. Sir Frederick M'Coy.
1880. Mr. Robert Etheridge.
1881. Sir Archibald Geikie.
1882. Prof. Jules Gosselet.
1883. Prof. H. R. Gœppert.
1884. Dr. Henry Woodward.
1885. Dr. Ferdinand von Rœmer.
1886. Mr. William Whitaker.
1887. The Rev. Peter B. Brodie.
1888. Prof. J. S. Newberry.
1889. Prof. James Geikie.
1890. Prof. Edward Hull.
1891. Prof. Waldemar C. Brögger.
1892. Prof. A. H. Green.
1893. The Rev. Osmond Fisher.
1894. Mr. William T. Aveline.
1895. Prof. Gustaf Lindström.
1896. Mr. T. Mellard Reade.
1897. Mr. Horace B. Woodward.
1898. Mr. Thomas F. Jamieson.
1899. { Dr. Benjamin Neeve Peach.
Dr. John Horne.
1900. Baron A. E. Nordenskiöld.
1901. Mr. A. J. Jukes-Browne.
1902. Mr. Frederic W. Harmer.
1903. Dr. Charles Callaway.
1904. Prof. George A. Lebour.
1905. Mr. Edward John Dunn.
1906. Mr. Charles T. Clough.
1907. Mr. Alfred Harker.
1908. Prof. Albert Charles Seward.
1909. Prof. Grenville A. J. Cole.
1910. Prof. Arthur Philemon Coleman.
1911. Mr. Richard Hill Tiddeman.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE 'MURCHISON GEOLOGICAL FUND.'

1873. Prof. Oswald Heer.
1874. Mr. Alfred Bell.
Prof. Ralph Tate.
1875. Prof. H. Govier Seeley.
1876. Dr. James Croll.
1877. The Rev. John F. Blake.
1878. Prof. Charles Lapworth.
1879. Mr. James Walker Kirkby.
1880. Mr. Robert Etheridge.
1881. Mr. Frank Rutley.
1882. Prof. Thomas Rupert Jones.
1883. Dr. John Young.
1884. Mr. Martin Simpson.
1885. Mr. Horace B. Woodward.
1886. Mr. Clement Reid.
1887. Dr. Robert Kidston.
1888. Mr. Edward Wilson.
1889. Prof. Grenville A. J. Cole.
1890. Mr. Edward B. Wethered.
1891. The Rev. Richard Baron.
1892. Mr. Beeby Thompson.
1893. Mr. Griffith John Williams.
1894. Mr. George Barrow.
1895. Prof. Albert Charles Seward.
1896. Mr. Philip Lake.
1897. Mr. Sydney S. Buckman.
1898. Miss Jane Donald.
1899. Mr. James Bennie.
1900. Mr. A. Vaughan Jennings.
1901. Mr. Thomas S. Hall.
1902. Sir Thomas H. Holland.
1903. Mrs. Elizabeth Gray.
1904. Dr. Arthur Hutchinson.
1905. Prof. Herbert L. Bowman.
1906. Dr. Herbert Lapworth.
1907. Dr. Felix Oswald.
1908. Miss Ethel Gertrude Skeat.
1909. Dr. James Vincent Elsden.
1910. Mr. John Walker Stather.
1911. Mr. Edgar Sterling Cobbold.

AWARDS OF THE LYELL MEDAL

UNDER THE CONDITIONS OF THE

'LYELL GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE

SIR CHARLES LYELL, BART., F.R.S., F.G.S.

The Medal 'to be cast in bronze and to be given annually' (or from time to time) 'as a mark of honorary distinction and as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) has deserved well of the Science,'—'not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions, at the discretion of the Council, for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper may be written.'

There is a further provision for suspending the award for one year, and in such case for the awarding of a Medal to 'each of two persons who have been jointly engaged in the same exploration in the same country, or perhaps on allied subjects in different countries, the proportion of interest always not being less to each Medal than one third of the annual interest.'

1876. Prof. John Morris.
1877. Sir James Hector.
1878. Mr. George Busk.
1879. Prof. Edmond Hébert.
1880. Sir John Evans.
1881. Sir J. William Dawson.
1882. Dr. J. Lycett.
1883. Dr. W. B. Carpenter.
1884. Dr. Joseph Leidy.
1885. Prof. H. Govier Seeley.
1886. Mr. William Pengelly.
1887. Mr. Samuel Allport.
1888. Prof. Henry A. Nicholson.
1889. Prof. W. Boyd Dawkins.
1890. Prof. Thomas Rupert Jones.
1891. Prof. T. McKenny Hughes.
1892. Mr. George H. Morton.
1893. Mr. Edwin Tulley Newton.
1894. Prof. John Milne.
1895. The Rev. John F. Blake.
1896. Dr. Arthur S. Woodward.
1897. Dr. George Jennings Hinde.
1898. Prof. Wilhelm Waagen.
1899. Lt.-Gen. C. A. McMahon.
1900. Dr. John Edward Marr.
1901. Dr. Ramsay H. Traquair.
1902. { Prof. Anton Fritsch.
Mr. Richard Lydekker.
1903. Mr. Frederick W. Rudler.
1904. Prof. Alfred G. Nathorst.
1905. Dr. Hans Reusch.
1906. Prof. Frank Dawson Adams.
1907. Dr. Joseph F. Whiteaves.
1908. Mr. Richard Dixon Oldham.
1909. Prof. Percy Fry Kendall.
1910. Dr. Arthur Vaughan.
1911. { Dr. Francis Arthur Bather.
Dr. Arthur Walton Rowe.

AWARDS OF THE BALANCE OF THE PROCEEDS OF THE 'LYELL GEOLOGICAL FUND.'

1876. Prof. John Morris.
1877. Mr. William Pengelly.
1878. Prof. Wilhelm Waagen.
1879. Prof. Henry A. Nicholson.
1879. Dr. Henry Woodward.
1880. Prof. F. A. von Quenstedt.
1881. Prof. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. The Rev. Norman Glass.
1882. Prof. Charles Lapworth.
1883. Mr. P. H. Carpenter.
1883. M. Ed. Rigaux.
1884. Prof. Charles Lapworth.
1885. Mr. Alfred J. Jukes-Browne.
1886. Mr. David Mackintosh.
1887. The Rev. Osmond Fisher.
1888. Dr. Arthur H. Foord.
1888. Mr. Thomas Roberts.
1889. Dr. Louis Dollo.
1890. Mr. Charles D. Sherborn.
1891. Dr. C. I. Forsyth Major.
1891. Mr. George W. Lamplugh.
1892. Prof. John Walter Gregory.
1892. Mr. Edwin A. Walford.
1893. Miss Catherine A. Raisin.
1893. Mr. Alfred N. Leeds.
1894. Mr. William Hill.
1895. Prof. Percy Fry Kendall.
1895. Mr. Benjamin Harrison.
1896. Dr. William F. Hume.
1896. Dr. Charles W. Andrews.
1897. Mr. W. J. Lewis Abbott.
1897. Mr. Joseph Lomas.
1898. Mr. William H. Shrubsole.
1898. Mr. Henry Woods.
1899. Mr. Frederick Chapman.
1899. Mr. John Ward.
1900. Miss Gertrude L. Elles.
1901. Dr. John William Evans.
1901. Mr. Alexander McHenry.
1902. Dr. Wheelton Hind.
1903. Mr. Sydney S. Buckman.
1903. Mr. George Edward Dibley.
1904. Dr. Charles Alfred Matley.
1904. Prof. Sidney Hugh Reynolds.
1905. Mr. E. A. Newell Arber.
1905. Dr. Walcot Gibson.
1906. Mr. William G. Fearnsides.
1906. Mr. Richard H. Solly.
1907. Mr. T. Crosbee Cantrill.
1907. Mr. Thomas Sheppard.
1908. Dr. Thomas Franklin Sibly.
1908. Mr. H. J. Osborne White.
1909. Mr. H. Brantwood Maufe.
1909. Mr. Robert G. Carruthers.
1910. Mr. F. R. Cowper Reed.
1910. Dr. Robert Broom.
1911. Dr. Charles Gilbert Cullis.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY THE LATE

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially 'as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than **45** years at his last birthday, thus probably not too old for further work, and not too young to have done much.'

1877. Prof. Othniel Charles Marsh.
1879. Prof. Edward Drinker Cope.
1881. Prof. Charles Barrois.
1883. Dr. Henry Hicks.
1885. Prof. Alphonse Renard.
1887. Prof. Charles Lapworth.
1889. Dr. J. J. Harris Teall.
1891. Dr. George Mercer Dawson.
1893. Prof. William J. Sollas.
895. Dr. Charles D. Walcott.
1897. Mr. Clement Reid.
1899. Prof. T. W. Edgeworth David.
1901. Mr. George W. Lamplugh.
1903. Dr. Henry M. Ami.
1905. Prof. John Walter Gregory.
1907. Dr. Arthur W. Rogers.
1909. Dr. John Smith Flett.
1911. Prof. Othenio Abel.

AWARDS OF THE PRESTWICH MEDAL,

ESTABLISHED UNDER THE WILL OF THE LATE

SIR JOSEPH PRESTWICH, F.R.S., F.G.S.

'To apply the accumulated annual proceeds . . . at the end of every three years, in providing a Gold Medal of the value of Twenty Pounds, which, with the remainder of the proceeds, is to be awarded . . . to the person or persons, either male or female, and either resident in England or abroad, who shall have done well for the advancement of the science of Geology; or, from time to time to accumulate the annual proceeds for a period not exceeding six years, and apply the said accumulated annual proceeds to some object of special research bearing on Stratigraphical or Physical Geology, to be carried out by one single individual or by a Committee; or, failing these objects, to accumulate the annual proceeds for either three or six years, and devote such proceeds to such special purposes as may be decided.'

1903. John Lubbock, Baron Avebury.
1906. Mr. William Whitaker.
1909. Lady Evans.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

Dr. H. C. BARLOW, F.G.S.

'The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science.'

1879. Purchase of Microscope.
1881. Purchase of Microscope-Lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Prof. Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.
1890. Mr. W. Jerome Harrison.
1892. Prof. Charles Mayer-Eymar.
1893. Purchase of Scientific Instruments for Capt. F. E. Younghusband.
1894. Dr. Charles Davison.
1896. Mr. Joseph Wright.
1896. Mr. John Storrie.
1898. Mr. Edward Greenly.
1900. Mr. George C. Crick.
1900. Dr. Theodore T. Groom.
1902. Mr. William M. Hutchings.
1904. Mr. Hugh John Ll. Beadnell.
1906. Mr. Henry C. Beasley.
1908. Contribution to the Fund for securing the Preservation of the Sarsen-Stones on Marlborough Downs, known as 'The Grey Wethers.'
1911. Mr. John Frederick Norman Green.

AWARDS OF THE PROCEEDS OF THE 'DANIEL PIDGEON FUND,'

FOUNDED BY MRS. PIDGEON, IN ACCORDANCE WITH THE WILL OF THE LATE

DANIEL PIDGEON, F.G.S.

'An annual grant derivable from the interest on the Fund, to be used at the discretion of the Council, in whatever way may in their opinion best promote Geological Original Research, their Grantees being in all cases not more than twenty-eight years of age.'

1903. Prof. Ernest Willington Skeats.
1904. Mr. Linsdall Richardson.
1905. Mr. Thomas Vipond Barker.
1906. Miss Helen Drew.
1907. Miss Ida L. Slater.
1908. Mr. James A. Douglas.
1909. Dr. Alexander Moncrieff Finlayson.
1910. Mr. Robert Boyle.
1911. Mr. Tressilian Charles Nicholas.

Estimates for

INCOME EXPECTED.

	£	*s.*	*d.*	£	*s.*	*d.*
Compositions				140	0	0
Arrears of Admission-Fees	81	18	0			
Admission-Fees, 1911	200	12	0			
				282	10	0
Arrears of Annual Contributions	130	0	0			
Annual Contributions, 1911, from Resident and Non-Resident Fellows	1900	0	0			
Annual Contributions in advance	75	0	0			
				2105	0	0
Sale of the Quarterly Journal, including Longmans' Account	......			160	0	0
Sale of other Publications	......			10	0	0
Miscellaneous Receipts	......			6	0	0
Interest on Deposit-Account	......			10	0	0
Dividends on £2500 India 3 per cent. Stock	75	0	0			
Dividends on £300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	15	0	0			
Dividends on £2250 London & North-Western Railway 4 per cent. Preference Stock	90	0	0			
Dividends on £2800 London & South-Western Railway 4 per cent. Preference Stock	112	0	0			
Dividends on £2072 Midland Railway 2½ per cent. Perpetual Preference Stock	51	16	0			
Dividends on £267 6*s.* 7*d.* Natal 3 per cent. Stock.	8	0	0			
				351	16	0
				£3065	6	0

[NOTE.—The accumulated interest on the Sorby and Hudleston Bequests, which will amount on December 31st, 1911, to £131 16*s.* 8*d.*, is not included in the above estimate of Income expected.]

the Year 1911.

EXPENDITURE ESTIMATED.

	£	*s.*	*d.*	£	*s.*	*d.*
House-Expenditure:						
Taxes		15	0			
Fire-Insurance and other Insurance	16	0	0			
Electric Lighting and Maintenance	50	0	0			
Gas	20	0	0			
Fuel	35	0	0			
Furniture and Repairs	50	0	0			
House-Repairs and Maintenance	40	0	0			
Annual Cleaning	25	0	0			
Tea at Meetings	16	0	0			
Washing and Sundry Expenses	30	0	0			
				282	15	0
Salaries and Wages, etc.:						
Assistant-Secretary	375	0	0			
,, half Premium Life-Insurance	10	15	0			
Assistant-Librarian	150	0	0			
Assistant-Clerk	150	0	0			
Junior Assistant	47	0	0			
House-Porter and Upper Housemaid	94	0	0			
Under Housemaid	49	18	0			
Charwoman and Occasional Assistance	14	0	0			
Accountants' Fee	10	10	0			
				901	3	0
Office-Expenditure:						
Stationery	30	0	0			
Miscellaneous Printing, etc.	60	0	0			
Postages and Sundry Expenses	75	0	0			
				165	0	0
Library (Books and Binding)				250	0	0
Library Catalogue:						
Cards	20	0	0			
Compilation	50	0	0			
				70	0	0
Publications:						
Quarterly Journal, including Commission on Sale	1000	0	0			
Postage on Journal, Addressing, etc.	100	0	0			
Record of Geological Literature	150	0	0			
Abstracts of Proceedings, including Postage	105	0	0			
List of Fellows	40	0	0			
				1395	0	0
				3063	18	0
Estimated excess of Income over Expenditure				1	8	0
				£3065	6	0

AUBREY STRAHAN, *Treasurer.*

January 27th, 1911.

Income and Expenditure during the

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance in the hands of the Bankers at January 1st, 1910	167	16	2			
,, Balance in the hands of the Clerk at January 1st, 1910	11	2	0			
				178	18	2
,, Compositions				70	0	0
,, Admission-Fees:						
Arrears	132	6	0			
Current	214	4	0			
				346	10	0
,, Arrears of Annual Contributions	159	14	0			
,, Annual Contributions for 1910:—						
Resident Fellows	1906	14	0			
Non-Resident Fellows	4	14	6			
,, Annual Contributions in advance	84	0	0			
				2155	2	6
,, Publications:						
Sale of Quarterly Journal: *						
,, Vols. i to lxv (less Commission £10 12*s.* 0*d.*)	157	7	0			
,, Vol. lxvi (less Commission £2 18*s.* 6*d.*)	45	14	6			
				203	1	6
,, Other Publications				8	1	1
,, Miscellaneous Receipts				11	1	3
,, Repayment of Income-Tax (1 year)				21	17	1
,, Interest on Deposit-Account				12	18	1
,, Legacy:						
Robert Hannah				100	0	0
,, Dividends (less Income-Tax):—						
£2500 India 3 per cent. Stock	70	12	4			
£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	14	2	6			
£2250 London & North-Western Railway 4 per cent. Preference Stock	84	15	0			
£2800 London & South-Western Railway 4 per cent. Preference Stock	105	9	4			
£2072 Midland Railway 2½ per cent. Perpetual Preference Stock	48	15	6			
£267 6*s.* 7*d.* Natal 3 per cent. Stock	7	11	0			
				331	5	8
				£3438	15	4

* A further sum is due from Messrs. Longmans & Co. for Journal-Sales £58 6 0

Special Funds.

Hudleston Bequest.

£1000 Canada 3½ °/₀ Stock.

	£	s.	d.
To Dividends	32	19	2
By Balance to next Acct.	32	19	2

Sorby Bequest.

£1000 Canada 3½ °/₀ Stock.

	£	s.	d.
To Dividends	32	19	2
By Balance to next Acct.	32	19	2

Year ended December 31st, 1910.

PAYMENTS.

	£	s.	d.	£	s.	d.
By House-Expenditure:						
Taxes		15	0			
Fire-Insurance and other Insurance	16	3	5			
Electric Lighting and Maintenance	54	16	5			
Gas	18	2	11			
Fuel	30	11	0			
Furniture and Repairs	60	15	9			
House-Repairs and Maintenance	38	8	10			
Annual Cleaning	27	18	4			
Tea at Meetings	14	10	9			
Washing and Sundry Expenses	22	13	2			
				284	15	7
,, Salaries and Wages:						
Assistant-Secretary	375	0	0			
,, half Premium Life-Insurance	10	15	0			
Assistant-Librarian	150	0	0			
Assistant-Clerk	150	0	0			
Junior Assistant	39	0	0			
House-Porter and Upper Housemaid	94	1	6			
Under Housemaid	49	18	0			
Charwoman and Occasional Assistance	8	17	0			
Accountants' Fee	10	10	0			
				888	1	6
,, Office-Expenditure:						
Stationery	19	0	11			
Miscellaneous Printing	68	8	11			
Postages and Sundry Expenses	66	19	10			
				154	9	8
,, Library (Books and Binding)				257	12	1
,, Library-Catalogue:						
Cards	24	5	0			
Compilation	50	0	0			
				74	5	0
,, Publications:						
Quarterly Journal, Vol. lxvi, Paper, Printing, and Illustrations	898	18	8			
Postage on Journal, Addressing, etc.	101	19	7			
Record of Geological Literature	162	12	0			
Abstracts, including Postage	100	5	7			
List of Fellows	62	16	6			
				1326	12	4
,, Balance in the hands of the Bankers at December 31st, 1910	423	8	2			
,, Balance in the hands of the Clerk at December 31st, 1910	29	11	0			
				452	19	2
				£3438	15	4

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

GEORGE W. YOUNG,
C. GILBERT CULLIS, } *Auditors.*

AUBREY STRAHAN, *Treasurer.*

January 27th, 1911.

Statement of Trust-Funds: December 31st, 1910.

‘WOLLASTON DONATION FUND.’ TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers’ at January 1st, 1910	32	1	2	By Cost of Medal	10	10	0
,, Dividends (less Income-Tax) on the Fund invested in £1073 Hampshire County 3 per cent. Stock	30	6	2	,, Award from the Balance of the Fund	21	11	2
,, Repayment of Income-Tax (1 year)	1	17	8	,, Balance at the Bankers’ at December 31st, 1910	32	3	10
	£64	5	0		£64	5	0

‘MURCHISON GEOLOGICAL FUND.’ TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers’ at January 1st, 1910	20	18	6	By Award to the Medallist	10	10	0
,, Dividends (less Income-Tax) on the Fund invested in £1334 London & North-Western Railway 3 per cent. Debenture Stock	37	13	8	,, Award from the Balance of the Fund	29	5	4
,, Repayment of Income-Tax (1 year)	2	5	0	,, Balance at the Bankers’ at December 31st, 1910	21	1	10
	£60	17	2		£60	17	2

‘LYELL GEOLOGICAL FUND.’ TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers’ at January 1st, 1910	53	7	0	By Award to the Medallist	25	0	0
,, Dividends (less Income-Tax) on the Fund invested in £2010 1*s.* 0*d.* Metropolitan 3½ per cent. Stock	66	5	0	,, First Award from the Balance of the Fund	22	9	2
,, Repayment of Income-Tax (1 year)	3	19	1	,, Second Award from the Balance of the Fund	22	9	1
				,, Balance at the Bankers’ at December 31st, 1910	53	12	10
	£123	11	1		£123	11	1

‘BARLOW-JAMESON FUND.’ TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers’ at January 1st, 1910	41	7	0	By Balance at the Bankers’ at December 31st, 1910	55	7	3
,, Dividends (less Income-Tax) on the Fund invested in £468 Great Northern Railway 3 per cent. Debenture-Stock	13	4	6				
,, Repayment of Income-Tax (1 year)		15	9				
	£55	7	3		£55	7	3

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	3	5	8	By Balance at the Bankers' at December 31st, 1910	9	11	8
„ Dividends (less Income-Tax) on the Fund invested in £210 Cardiff 3 per cent. Stock	5	18	8				
„ Repayment of Income-Tax (1 year)		7	4				
	£9	11	8		£9	11	8

'GEOLOGICAL RELIEF FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	33	5	7	By Grants	2	2	0
„ Dividends (less Income-Tax) on the Fund invested in £139 3*s.* 7*d.* India 3 per cent. Stock	3	18	8	„ Balance at the Bankers' at December 31st, 1910	35	6	10
„ Repayment of Income-Tax (1 year)		4	7				
	£37	8	10		£37	8	10

'PRESTWICH TRUST FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	44	7	7	By Balance at the Bankers' at December 31st, 1910	65	6	9
„ Dividends (less Income-Tax) on the Fund invested in £700 India 3 per cent. Stock	19	15	8				
„ Repayment of Income-Tax (1 year)	1	3	6				
	£65	6	9		£65	6	9

'DANIEL PIDGEON FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	15	18	5	By Award	30	6	4
„ Dividends (less Income-Tax) on the Fund invested in £1019 1*s.* 2*d.* Bristol Corporation 3 per cent. Stock	28	15	10	„ Balance at the Bankers' at December 31st, 1910	16	3	5
„ Repayment of Income-Tax (1 year)	1	15	6				
	£46	9	9		£46	9	9

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

AUBREY STRAHAN, *Treasurer.*

January 27th, 1911.

GEORGE W. YOUNG,
C. GILBERT CULLIS, } *Auditors.*

Statement of Trust-Funds: December 31st, 1910.

'WOLLASTON DONATION FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	32	1	2	By Cost of Medal	10	10	0
,, Dividends (less Income-Tax) on the Fund invested in £1073 Hampshire County 3 per cent. Stock	30	6	2	,, Award from the Balance of the Fund	21	11	2
,, Repayment of Income-Tax (1 year)	1	17	8	,, Balance at the Bankers' at December 31st, 1910	32	3	10
	£64	5	0		£64	5	0

'MURCHISON GEOLOGICAL FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	20	18	6	By Award to the Medallist	10	10	0
,, Dividends (less Income-Tax) on the Fund invested in £1334 London & North-Western Railway 3 per cent. Debenture Stock	37	13	8	,, Award from the Balance of the Fund	29	5	4
,, Repayment of Income-Tax (1 year)	2	5	0	,, Balance at the Bankers' at December 31st, 1910	21	1	10
	£60	17	2		£60	17	2

'LYELL GEOLOGICAL FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	53	7	0	By Award to the Medallist	25	0	0
,, Dividends (less Income-Tax) on the Fund invested in £2010 1s. 0d. Metropolitan 3½ per cent. Stock	66	5	0	,, First Award from the Balance of the Fund	22	9	2
,, Repayment of Income-Tax (1 year)	3	19	1	,, Second Award from the Balance of the Fund	22	9	1
				,, Balance at the Bankers' at December 31st, 1910	53	12	10
	£123	11	1		£123	11	1

'BARLOW-JAMESON FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	41	7	0	By Balance at the Bankers' at December 31st, 1910	55	7	3
,, Dividends (less Income-Tax) on the Fund invested in £468 Great Northern Railway 3 per cent. Debenture-Stock	13	4	6				
,, Repayment of Income-Tax (1 year)		15	9				
	£55	7	3		£55	7	3

'BIGSBY FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	3	5	8	By Balance at the Bankers' at December 31st, 1910	9	11	8
,, Dividends (less Income-Tax) on the Fund invested in £210 Cardiff 3 per cent. Stock	5	18	8				
,, Repayment of Income-Tax (1 year)		7	4				
	£9	11	8		£9	11	8

'GEOLOGICAL RELIEF FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	33	5	7	By Grants	2	2	0
,, Dividends (less Income-Tax) on the Fund invested in £139 3s. 7d. India 3 per cent. Stock.............	3	18	8	,, Balance at the Bankers' at December 31st, 1910	35	6	10
,, Repayment of Income-Tax (1 year)		4	7				
	£37	8	10		£37	8	10

'PRESTWICH TRUST FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	44	7	7	By Balance at the Bankers' at December 31st, 1910	65	6	9
,, Dividends (less Income-Tax) on the Fund invested in £700 India 3 per cent. Stock	19	15	8				
,, Repayment of Income-Tax (1 year)	1	3	6				
	£65	6	9		£65	6	9

'DANIEL PIDGEON FUND.' TRUST ACCOUNT.

RECEIPTS.	£	s.	d.	PAYMENTS.	£	s.	d.
To Balance at the Bankers' at January 1st, 1910	15	18	5	By Award	30	6	4
,, Dividends (less Income-Tax) on the Fund invested in £1019 1s. 2d. Bristol Corporation 3 per cent. Stock.	28	15	10	,, Balance at the Bankers' at December 31st, 1910	16	3	5
,, Repayment of Income-Tax (1 year)	1	15	6				
	£46	9	9		£46	9	9

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

AUBREY STRAHAN, *Treasurer.*
January 27th, 1911.

GEORGE W. YOUNG, } *Auditors.*
C. GILBERT CULLIS, }

Statement relating to the Society's Property: December 31st, 1910.

	£	*s.*	*d.*	£	*s.*	*d.*
Balance in the Bankers' hands, December 31st, 1910:						
On Current Account	423	8	2			
Balance in the Clerk's hands, December 31st, 1910	29	11	0	452	19	2
Due from Messrs. Longmans & Co., on account of Quarterly Journal, Vol. LXVI, etc.	58	6	0			
Arrears of Admission-Fees	100	16	0			
Arrears of Annual Contributions	235	6	0	394	8	0
				£847	7	2
Funded Property, at cost price:—						
£2500 India 3 per cent. Stock	2623	19	0			
£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	502	15	3			
£2250 London & North-Western Railway 4 per cent. Preference Stock	2898	10	6			
£2800 London & South-Western Railway 4 per cent. Preference Stock	3607	7	6			
£2072 Midland Railway $2\frac{1}{2}$ per cent. Perpetual Preference Stock	1850	19	6			
£267 6*s.* 7*d.* Natal 3 per cent. Stock	250	0	0			
£2000 Canada $3\frac{1}{2}$ per cent. Stock	1982	11	0			
				13,716	2	9

[*N.B.—The above amount does not include the value of the Collections, Library, Furniture, and Stock of unsold Publications. The value of the Funded Property of the Society at the prices ruling at the close of business on December 31st, 1910, amounted to £11,703 16s. 9d.*]

AUBREY STRAHAN, *Treasurer.*

January 27th, 1911.

AWARD OF THE WOLLASTON MEDAL.

In handing the Wollaston Medal, awarded to Prof. WALDEMAR CHRISTOFER BRÖGGER, F.M.G.S., to His Excellency BENJAMIN VOGT, Minister Plenipotentiary for the Kingdom of Norway, the PRESIDENT addressed him as follows:—

Your EXCELLENCY,—

It is most fitting that the medal which bears the honoured name of Wollaston, and was founded by that eminent and philosophical mineralogist, should be awarded to Prof. Brögger, who is not only an accomplished chemist and a skilful mineralogist, but a great petrologist. If he had published nothing but his work on these subjects, he would stand in the first rank of living geologists. But he has done far more. His researches on the Cambrian and Ordovician rocks of his own country have proved him to be a brilliant palæontologist and stratigrapher. His detailed mapping and interpretation of the structure of the Christiania area and his explanation of the origin of the Christiania Fjord, have proved him to be a tectonic geologist of the highest order. His researches on the differentiation of rock-magmas have made him one of our foremost teachers of petrogenesis. He has conducted an exhaustive research on the Glacial and post-Glacial changes in Southern Norway, and has expressed his results so cogently that we seem to see with our own eyes the ice-sheets retreating, the seas advancing and retiring, and to feel the climate slowly changing during the deposition of the clays and shell-gravels of your country. He has brought his work on the strand-lines into touch with the ages of man, and has even endeavoured to express these later stages of geological time in terms of years. Nor has his life-work been devoted to science alone; he has served his fellow-countrymen as a member of the National Legislature and his colleagues as the Rector of his University.

But it is not so much the quantity as the quality of Prof. Brögger's work that constitutes his claim to the Wollaston Medal. His scientific training has been so thorough, his insight so deep, and his outlook so wide, that in every subject which he has touched his work has become a mine of fact, a model of expression, an example of close and accurate reasoning, and a revelation of new principles. In an age of specialization he is a specialist, but a specialist in almost every branch of his science. That it should have fallen to

one man to do so much and so well almost passes belief, but our libraries are enriched by his books and memoirs, and the work of our young men is inspired, improved, and encouraged by his example.

We ask your Excellency to transmit this Medal to Prof. Brögger, and with it to convey to him the deepest respect of his British colleagues, and the best wishes of his many friends in this country.

The NORWEGIAN MINISTER expressed his pride and pleasure in receiving on behalf of his distinguished countryman and friend the highest award which it was in the power of so venerable and learned a Society to confer, and read the following communication which had been sent to him by Prof. Brögger:—

'Twenty years ago the Geological Society of London did me the great honour to award to me the Murchison Medal. The Society now having awarded to me its highest honour, the Wollaston Medal, I am led to hope that also during the two decenniums that have elapsed I have been able to yield some contribution of general interest to geological science.

'Allow me on this occasion to assure you, that no other appreciation could have been more unexpected or more valued by me than the unanimous award of the Wollaston Medal by the Council of the Geological Society, an honour so surprising to me, that even in my dreams I could never have expected to attain it. I am therefore so much the more grateful for this kind valuation of my scientific results.

'The roll of the Wollaston Medal, from the time of its first recipient, the great master, William Smith, until this day, comprises an unsurpassed series of founders and constructors of various branches of geological science. Looking on this roll, comprising also a number of those who were my valued instructors in my youth—the few still living amongst them being now seniors and Nestors of their science—I obtain an excellent scale of the high importance of such an appreciation from the oldest and most renowned Geological Society of the world.

'At the same time, these dear old illustrious names on the roll speak to me as a sad and serious memento of the short lifetime that is left, a reminder to devote the few years that may still remain for me to complete my main lifework: "The History of the Eruptive Province of the Kristiania Region," the finishing of which, by the force of circumstances, has been interrupted and postponed by official duties for several years.

'Respectfully thanking you for this precious memento, I bow my head, and will do my best to follow its voice.

W. C. BRÖGGER.'

'Kristiania, February 9th, 1911.'

AWARD OF THE MURCHISON MEDAL.

The PRESIDENT then handed the Murchison Medal, awarded to Mr. RICHARD HILL TIDDEMAN, M.A., to Prof. E. J. GARWOOD, Sec.G.S.,

for transmission to the recipient, and addressed him in the following words :—

Professor GARWOOD,—

Ever since the beginning of Mr. Tiddeman's work for the Geological Survey on the borders of Yorkshire and Lancashire, he has kept his eyes open to the observation of exceptional facts and his mind employed in working out explanations for them. Thus he has endowed our Science with the fertile suggestions which make workers think on new lines. The excavation of the Victoria Cave, with which he had so much to do, gave us valuable information on the history of the Pleistocene Mammalia; his work on the glaciation of North Lancashire still remains 'a model and a basis for Glacial work all over the country'; his observations on the faunas of the Carboniferous 'reef-knolls' of the North of England have put on record a wealth of observation and reasoning which will contribute no little to the solution of the problems presented by those remarkable structures; and his researches upon the raised beaches of Gower, covered with Glacial deposits, have extended the area of known Pleistocene movement beyond Yorkshire and Cork. Those who have been with him in the field have good cause to be especially grateful to him for the generosity with which he has placed the riches of his knowledge at their disposal. He has helped not only to advance Geology but to make geologists, and in so doing he has invested his talent at compound interest.

As a member of the Geological Survey, and one of the last of that body who served under Sir Roderick Murchison, he has well merited the award of the medal which bears that honoured name.

Prof. GARWOOD expressed deep regret, which he felt was shared by all present, that a sudden attack of influenza had prevented the recipient from attending in person, and read, in accordance with Mr. Tiddeman's request, the following reply :—

'The award has given me the greatest possible pleasure and satisfaction, and I owe to the President and Council my warmest thanks.

'I regret that I have not done more to merit it; but I hope that I may take the Award as signifying that some of my former heresies have been more or less accepted as orthodoxies by my present friends and colleagues, and for this I may go on my way rejoicing.

R. H. TIDDEMAN.'

Award of the Lyell Medals.

In presenting one of the two Lyell Medals, awarded this year, to Dr. Francis Arthur Bather, F.R.S., the President addressed him as follows:—

Dr. Bather,—

To devote one's self to the mastery and elucidation of a single group of organisms, and that a large one, demands in most cases so close an application to the study, that neither time nor energy is available for other studies or occupations. This, however, has not been the case with you. Outside your own special orders of the Echinoderma you have dealt with several other groups of the Invertebrata, and have been entrusted with the writing of the British Museum Handbook on the fossil members of this division of the animal kingdom. You have paid attention to the phenomena of denudation by wind, as well as to general stratigraphical questions. You have travelled far and frequently in the pursuit of your comparative study of the Foreign and Colonial Museums, and have contributed much information and many valuable suggestions on Museum management, organization, and arrangement to your colleagues in this work. You have brought your ideas and methods for the popular exposition of Geology before the public at the recent International Exhibitions in London, and in more than one case have been exceptionally successful in achieving your objects. You have made yourself a recognized authority on zoological nomenclature.

But these are all by-products. You have ever kept before your mind the steadfast resolve to bring into order, to systematize and classify, and to describe clearly, faithfully, and precisely, certain important fossil forms of the Echinoderma, and especially the Crinoids. I would especially mention your series of papers on British Fossil Crinoids, your important memoir on the Crinoidea of Gotland, and your latest published work on the Triassic Echinoderms of Bakony. Nor must I omit to add your important contribution on Echinoderma to Sir Ray Lankester's Treatise on Zoology.

In your task you have been so successful that the Council have decided to ask you to accept this year a Lyell Medal, which was intended by its founder to be awarded 'for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced.'

Dr. Bather, in reply, said:—

Mr. President,—

I had thought of much to say on this occasion, but the generous and flattering terms in which you have recounted the things that I have done have made me think rather of those things that I have left undone. If the little that I have done has seemed of such service to Geology as to merit this high distinction, while I am proud to receive it, I cannot forget the friends in all parts of the world who have so greatly facilitated my work by the loan of valuable specimens. And the thought of them again reminds me of the material accumulated, but still untouched. A palæontologist at the British Museum is often envied, much as Dionysius of Syracuse was envied by Damocles. If any Damocles were to take my place he would see, it is true, a rich feast of Cystids and Crinoids laid before him. But the chains of office would perpetually hinder him from feeding, and every day he would dread the fall of a sword in the shape of a peremptory letter demanding the immediate return of some necessary specimen.

It is my hope, Sir, that this award by so high a tribunal may convince my friends and superiors that I really have made good use of the rich material entrusted to me; certainly it will encourage me to make my own future labours no less deserving of their continued patience. For these reasons and for many others, which must remain unexpressed, I offer to the Council my heartfelt thanks.

The President then presented the other Lyell Medal to Dr. Arthur Walton Rowe, F.G.S., addressing him as follows:—

Dr. Rowe,—

It is no small pleasure to me that it is my duty, as President of the Geological Society, to ask your acceptance of the Lyell Medal which the Council of the Society have awarded to you, in recognition of the great service which you have rendered to British Geology by your researches on the succession and distribution of the zones of the English Chalk. Using delicate and refined means of your own for the development of the fossils, and collecting the latter from the successive horizons with the most scrupulous care, you soon convinced yourself that the key to the evolution of the Echinoids and the basis for their classification was to be found in their succession

in time. The first important outcome of your work was the classic paper on the evolution of the genus *Micraster* published by this Society in 1899. The lines of advance in these organisms having thus been made out, you proceeded to use the characteristic forms as time-indices, with the result that you were able, not only to make a satisfactory subdivision of the White Chalk in Kent, but to extend the zonal lines thus marked out throughout the country. In this manner you carried on the work so ably begun by Prof. Charles Barrois, and erected a worthy superstructure upon the solid foundations laid by him. The influence which your research has exerted upon other investigators in stimulating them to work, either in direct association with yourself or independently, but always assisted and encouraged by your active help and sympathy, is a sufficient testimony to its value.

Dr. ROWE replied in the following words:—

Mr. PRESIDENT,—

That every man is glad to have his work recognized is, I suppose, a truism; but, while I deeply appreciate the all too kind remarks which you have just made, I cannot but feel that the recognition is on far too generous a scale. Very warmly I welcome the reference which you have made to my amateur colleagues in the field. We have but one common aim, and that is to trace the centres of distribution of species in the Chalk, together with their vertical and horizontal range, and especially to work out the fascinating problems in evolution in which that formation is so rich. And, if a certain little biological indiscretion, which I had the temerity to offer to the Council in the year 1899, has borne fruit in this last direction, I shall not regret the anxious complications which attended its somewhat protracted parturition.

But, while I claim all praise for the amateur worker, let us not forget the labours of one whose philosophical and masterly grasp of the whole Cretaceous System has laid us all under a lasting obligation. I refer, of course, to Mr. A. J. Jukes-Browne.

All of us, however, professional and amateur worker alike, owe our allegiance to, and draw our inspiration from, that great Frenchman, Charles Barrois. But for him, we should still be floundering in the pre-zonal chaos of a 'Chalk with flints' and a 'Chalk without flints.' As I have said, when speaking in another place, I ask no better verdict from posterity than to be regarded as a faithful

exponent of Barrois. Higher praise no worker in the Chalk can ask than this, nor can he attain to higher office.

And, Sir, in tendering to you and to the Council my grateful thanks for this high honour, it only remains for me to say that I accept it, not for my own merits, but as a recognition of the splendid achievements of my fellow-workers in this most fruitful field of investigation.

Award of the Bigsby Medal.

The President, in presenting to Prof. Othenio Abel, Ph.D., the Bigsby Medal, addressed him as follows :—

Professor Abel,—

The Bigsby Medal has in former years been awarded to workers in many branches of Geology; to stratigraphers, petrologists, palæontologists, and to those whose special subject has been tectonics or physiography: it has been given to the geologists of many lands. It is, however, more than thirty years since it was given to one whose chief work lay in the domain of Vertebrate Palæontology, and it has never yet been awarded to a native of your country.

In awarding it on this occasion, the Council wish to mark their appreciation of your investigations upon the higher Vertebrata, more especially on the Cetacea and Sirenia. Your great memoirs on the Upper Miocene Toothed Whales of Belgium and on the Sirenians of the Mediterranean Territory of Austria are admirable examples of descriptive work, completed by philosophical deductions; while your numerous smaller papers, both on mammals and on lower vertebrates, are full of suggestive speculations based on a detailed study of all the available materials.

The vigour and thoroughness of the work that you have accomplished make it clear that, in the words of the Founder, 'you are not too old for further work,' while the number and excellence of your publications prove that 'you are not too young to have done much.'

Count Alexander Hoyos, Secretary to the Imperial and Royal Austro-Hungarian Embassy, expressed, on behalf of the Ambassador, his Excellency's regret at his unavoidable absence on that

occasion, as well as his gratification that so signal an honour had been conferred by the premier Geological Society of the world upon his distinguished fellow-countryman, Prof. Abel, and thus for the first time upon a native of Austria.

Prof. ABEL, having requested permission to use the German language in expressing his thanks, replied as follows:—

Herr PRÄSIDENT,—

Ich bitte, für die Verleihung der Bigsby Gold Medal meinen wärmsten und tiefgefühlten Dank entgegennehmen zu wollen.

Die Zuwendung der Bigsby Medal bedeutet für mich eine ausserordentliche und unerwartete Ehrung, und ich empfinde dieselbe in ihrer ganzen Bedeutung. Ich schätze diese Auszeichnung um so höher, als sie mir gerade von Seiten der Geological Society of London verliehen wurde, der ältesten und unbestritten angesehensten geologischen Gesellschaft der Welt; ihre Mitgliederliste umfasst seit ihrer Gründung bis auf den heutigen Tag Namen, deren Träger auf dem Gebiete der Geologie und Paläontologie unsere Führer und Meister gewesen sind.

Ich bin stolz darauf als der erste Œsterreicher dieselbe Medaille erhalten zu haben, welche 1877 an Othniel Charles Marsh und 1879 an Edward Drinker Cope verliehen wurde. Aber diese Erinnerung weckt in mir die Besorgnis, ob ich imstande sein werde, mich wie Marsh und Cope in Zukunft der mir verliehenen Auszeichnung nicht unwürdig zu erweisen.

Seit einer Reihe von Jahren mit Untersuchungen über fossile Vertebraten beschäftigt, war es stets mein Bestreben, ihre genetischen Zusammenhänge und Entwicklungswege sowie die Geschichte ihrer Anpassungen zu verfolgen. Auf dem Wege weiterschreitend, den mir mein hochverehrter Freund Louis Dollo gewiesen hat, will ich auch ferner meine ganze Kraft diesen Untersuchungen zuwenden, um mich der mir heute zuteil gewordenen Ehrung nicht unwürdig zu erweisen; die Bigsby Medal wird ein neuer Ansporn für mich sein, in meinen wissenschaftlichen Arbeiten nicht zu erlahmen.

AWARD FROM THE WOLLASTON DONATION FUND.

The PRESIDENT then presented the Balance of the Proceeds of the Wollaston Donation Fund to Prof. OWEN THOMAS JONES, M.A., addressing him as follows:—

Professor JONES,—

Up to within the last few years, the wide-spreading and rugged expanse of Central Wales was tinted upon our geological maps of a uniform pink colour, almost as if it were composed of the strata of a single sub-formation. But, little by little, geologists of the younger generation have been working out the details of its complicated structure, collecting the fossils, and bringing its component rock-groups into line and harmony with their zone-fellows elsewhere. In this work of reformation you have taken a full share. While still a member of the Geological Survey, you devoted your holidays to the enthusiastic study of these complicated strata of your native land, and in your Plynlimmon paper you have most successfully unravelled the sequence and structure of that 'heart of Mid-Wales' and of much of the ground to the west. I have much pleasure in handing to you the Balance of the Proceeds of the Wollaston Fund, which the Council have awarded to you, in recognition of the good work that you have done, and as an incentive to you to complete it,—a task which will be rendered easier by your appointment as Professor of Geology in the University College of Wales at Aberystwyth.

AWARD FROM THE MURCHISON GEOLOGICAL FUND.

In presenting the Balance of the Proceeds of the Murchison Geological Fund to Mr. EDGAR STERLING COBBOLD, F.G.S., the PRESIDENT addressed him in the following words:—

Mr. COBBOLD,—

Although the County of Shropshire was to Murchison a veritable Golconda, he was not able to remove all its treasure or to wrest all its secrets, but left a generous reward for his many successors. Among them, by your excavations in a district rendered difficult by earth-movement and thick soil-covering, you have succeeded in

obtaining a new Cambrian sub-fauna and an array of new genera and species of trilobites. You have not only made important contributions to what was hitherto known of the local succession of the subdivisions of those ancient rocks, but you have by your figures and descriptions added much to our previous knowledge of their fossils. It is appropriate that the Murchison Fund should pass into 'Siluria' and to one working on Older Palæozoic rocks, as a token of the good-will of your fellow-workers, a mark of their pleasure in your achievement, and an expression of their confidence in your future work.

AWARD FROM THE LYELL GEOLOGICAL FUND.

The PRESIDENT then presented to Dr. CHARLES GILBERT CULLIS, F.G.S., the Balance of the Proceeds of the Lyell Geological Fund, addressing him as follows:—

Dr. CULLIS,—

I need hardly express the pleasure that it gives me to hand the Balance of the Lyell Fund to a colleague for whom I have so much respect, and in whose judgment and ability I place so much confidence. You are able to look back upon a great number of students who have passed out into the world bearing the marks of your training, and you have reason to be proud of the work that they are doing. Your original contribution to the study of the core of the Funafuti Boring, with its careful record and explanation of the occurrence of calcite, aragonite, and dolomite therein; your work on the Forest of Dean and May Hill; and your discovery of the occurrence of dolomite crystals in the Keuper Marls, have all been the fruit of painstaking research, with the gratifying result of forwarding the researches of others. All those who have heard you lecture on your own work or on other geological subjects, have been greatly impressed by your careful choice of matter, the charm of your style, and the lucidity of your expression. Certainly this Award is given to one by whom 'Geology has been materially advanced.'

AWARD FROM THE BARLOW-JAMESON FUND.

In presenting an Award from the Proceeds of the Barlow-Jameson Fund to Mr. JOHN FREDERICK NORMAN GREEN, M.A., the PRESIDENT addressed him in the following words :—

Mr. GREEN,—

It is not often that it is given to a geologist to succeed in producing conviction by a single paper, still less by his first contribution to the Science: but such has been your good fortune in the paper published by this Society on the rocks of St. David's. The appropriateness of your methods, your careful recognition of lithological horizons, the accuracy and detailed minuteness of your mapping, even the careful selection of the most conclusive spot for excavation, have engendered such confidence in the result, that we may regard as solved one of the chief difficulties in a most complex region. The Council have made to you an Award from the Barlow-Jameson Fund 'for the advancement of Geological Science,' in the assurance that you will carry the same accuracy and delicacy of work into other fields.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

Prof. William Whitehead Watts, Sc.D., M.Sc., F.R.S.

During this year death has laid his heavy hand more lightly than is his wont upon our ranks. It is not often that a year passes without the loss of one or more of those eminent men whose names adorn the lists of our Foreign Members and Correspondents. Prof. W. P. Blake, though a citizen of the United States, was on our home list; and our other losses include Charles Bird, Arthur Brown, Dr. T. Cooke, E. Cross, Prebendary W. H. Egerton, the Rev. de Charles Evans, C. E. Fox-Strangways, G. R. Godson, T. M. Heaphy, J. C. Melliss, Captain G. E. Shelley, W. Smethurst, Charles Smith, A. H. Stokes, F. Tendron, Major-General W. E. Warrand, the Rev. R. B. Watson, the Rev. G. F. Whidborne, and J. T. Young. Notices of the lives of those who have been closely associated with the advance of Geology are given below, and to them have been added notices of the following :—J. Randall, a Fellow until 1877; J. R. Dakyns, who, though he published papers in our Journal, never actually joined the Society; and T. R. Polwhele, a Fellow who died in 1909. For the notice of the last I am indebted to Mr. H. B. Woodward, and that of J. R. Dakyns is founded on a memoir written by Mr. G. W. Lamplugh for the Yorkshire Geological Society. The list contains the name of one centenarian and of one Fellow who attained the ripe age of 98 years; the youngest died at 64, and the average age of those that I have been able to trace is 76.

The Rev. William Henry Egerton, Prebendary of Lichfield, was born on November 13th, 1811, and was the fourth son of the Rev. Sir Philip Grey Egerton, the ninth baronet. He was educated privately, graduated at Brasenose College, Oxford, in 1834, and was elected to a Fellowship at his College. He was nominated by Lord Brownlow to the Rectory of Ellesmere (Salop) in 1845, and transferred to the Rectory of Whitchurch in the following year, a cure which he held for 62 years until his retirement in 1908. In that year he answered with his own hand a letter of congratulation, which the Secretary was instructed by the Council to write on his birthday to one who for many years had been the 'Father' of the Society. He was a Fellow for 78 years, and died on December 1st, 1909, at the age of 98 years. His only communication to the

Society was a letter written to Sir Charles Lyell as Foreign Secretary in 1834, on the delta formed by the river Kander, since it was turned into a new course in 1713. This was published in vol. ii of the Proceedings.[1]

John Randall was born at Broseley (Shropshire) on September 1st, 1810. He early attained considerable skill in the art of painting on china, and, adopting this as his profession, was engaged in it until in 1891 his failing eyesight compelled him to give up the work. His special branch was the painting of birds, in which he obtained great proficiency. Joining the Geological Society in 1863 and remaining a Fellow until 1877, he published one paper in our Journal in conjunction with G. E. Roberts, recording their joint discovery of the Upper Ludlow Bone-bed in Linley Brook, near Bridgnorth. Most of his other papers were contributed to the 'Colliery Guardian,' and referred to the Midland iron-ores. His literary activity was considerable, and among his works the 'History of Broseley,' the 'Severn Valley,' and the 'Clay Industries' contained chapters and references dealing with the geology of the Shropshire Coalfield and its borders, on which he had made himself an authority, mainly by his own field observations. At the 1851 Exhibition he received a bronze medal for his collection of minerals and fossils, and in 1867 he was sent by the Society of Arts to the Paris Exhibition, where he reported on the manufacture of both pottery and iron. After he had passed the age of 90, he dictated to his daughter the volume on the arts and industries of Shropshire for the 'Victoria History' of the county. On June 7th, 1909, the freedom of the Borough of Wenlock was conferred on him in his 99th year, and it is stated that he signed the Borough Roll without the aid of spectacles. He lived to celebrate his hundredth birthday, but died shortly afterwards.

Thomas Roxburgh Polwhele, M.A., whose death took place at Polwhele, near Truro, on September 2nd, 1909, was born in 1831, and educated at Cambridge, where his interest in geology was aroused by the teachings of Sedgwick. In 1857 he joined the staff of the Geological Survey under Murchison and Ramsay, and in the following year became a Fellow of this Society. During his official

---

[1] For the particulars given in these notices I am much indebted to the 'Geological Magazine,' 'Nature,' the Proceedings of the Yorkshire Geological Society, the 'Times,' and to several newspapers.

field-work he was occupied in parts of Hampshire, Surrey, Oxfordshire, and Buckinghamshire, and contributed notes to Memoirs prepared by his colleagues W. Whitaker and A. H. Green. An able and painstaking worker, he remained but five years on the Geological Survey, as he succeeded to the Polwhele estate in 1862. Thereafter his duties as a landowner occupied his chief attention; he became a Justice of the Peace and Deputy Lieutenant. He was, however, chosen President of the Royal Geological Society of Cornwall in 1896 and 1897, and delivered addresses on 'The Relation of other Sciences to Geology' and on 'The Physical Geology of the Earth.' [H. B. W.]

Major-General WILLIAM EDMUND WARRAND, R.E., was born in 1831. He passed through the Indian Mutiny, and in 1860 was appointed head of the Civil Engineering College in Calcutta. He became a Fellow of this Society in 1859, and died on October 22nd, 1910, at the age of 79.

Captain GEORGE ERNEST SHELLEY, a nephew of the poet, joined this Society in 1862. Born in 1840, he entered the Grenadier Guards in 1863, and, after a short service, retired. After his retirement he was attached to a Commission sent out by the Government to South Africa on a geological survey. His interest was, however, attracted by the study of ornithology, and to this he devoted his chief attention, publishing several important works and monographs on the subject. He died in December, 1910.

The Rev. ROBERT BOOG WATSON became a Fellow of the Society in 1864. He was a Chaplain to the Forces, and later on was Minister of the Scottish Church in Madeira. He wrote a paper, published in abstract in the Quarterly Journal for 1866, in which he advocated a marine origin for the Parallel Roads of Glenroy, in opposition to the views expressed by Agassiz and Jamieson. He also wrote on the Boulder Clay at Greenock and the shelly drifts of Southern Arran. He died in June, 1910.

THEODORE COOKE, C.I.E., LL.D., M.A., F.L.S., died on November 5th, 1910, at the age of 74. He had been a Fellow of this Society since 1866. After winning high distinction at Trinity College, Dublin, he went out to India as an engineer, and there completed several important works, including the iron bridge at

Bassein, 4312 feet long. He was appointed Principal of the Poona College of Science, and also Director of the Botanical Survey of Western India. He retired from India in 1893, and was for the next three years Technical Sub-Director of the Imperial Institute.

Charles Edward Fox-Strangways died on March 5th, 1910, at the age of 66. He was born at Rewe, near Exeter, where his father, the Rev. Henry Fox-Strangways, a grandson of the first Earl of Ilchester, was Rector. He was educated at Eton, and, proceeding afterwards to the University of Göttingen, he studied chiefly the sciences of mineralogy, chemistry, and physics. Here also he saw something of the war of 1866, in the course of which he assisted Sartorius von Waltershausen, the Professor of Mineralogy and Geology, to conceal his collection of minerals, in order to prevent it from falling into the hands of the belligerents. In the following year he received an appointment as Assistant-Geologist to the Geological Survey, under Murchison. He attained the rank of Geologist in 1879, and was promoted to District-Geologist in 1901. He joined the Geological Society in 1873, served on the Council from 1905 to 1908, and was for a couple of years Secretary of the Geological Society Club.

The bulk of his published work is contained in the Memoirs of the Geological Survey, and he read no papers to this Society. He, however, communicated many papers to the Yorkshire Geological Society, to the Leicestershire Literary & Philosophical Society, and to other local institutions. After some early work near Todmorden and across the Yorkshire Coalfield, he surveyed a considerable area near Harrogate and Knaresborough. Then, settling at Scarborough, he carried his work across the Vale of York, to the Jurassic and Cretaceous rocks of the Yorkshire Wolds and Moors. Many of his maps were published on the 6-inch scale as well as the ordinary 1-inch scale, and some of his Memoirs have had the unusual distinction of passing into a second edition. His sympathies were by no means confined to the solid rocks, but he was keenly interested in physiographic questions and made many important observations and suggestions on the glacial phenomena of the Vale of York, the Vale of Pickering, and the Yorkshire Moors. He closed his official Yorkshire work with the publication of his contribution to the Memoir on the Jurassic Rocks of Britain, two portly volumes on the Jurassic Rocks of Yorkshire.

On his transfer to the Midlands in 1889 he moved his residence to Leicester. Here he was engaged on the re-survey of parts of the Coalfields of Central England with the intervening ground. Besides several sheet-memoirs, he was entirely responsible for the Memoirs on the South Derbyshire and Leicestershire Coalfields. From 1901 onwards he was in charge of the officers engaged in surveying the Midland District, until in 1904 he retired from the service. While resident in Leicester he took much interest in the work of the Leicestershire Literary & Philosophical Society, and especially in its excursions, many of which he planned and directed. The longer excursions of 1903 and 1904 to Scarborough and Whitby were led by him. It was at Leicester that the present writer had the pleasure of making his acquaintance, and of working with him on the geology of Charnwood Forest.

Weakened health, due to an affected heart, gradually impaired his wonted activity, and made him glad to retire when he had reached the age-limit. He moved to Hampstead, and although unable to take part in field-work, he carried on his literary work to the end. He succeeded in practically completing an exhaustive bibliography of Yorkshire, which it is to be hoped will soon be published; but he was unable to finish the Memoir on the Thicknesses of the British Formations, on which he had begun to amass material.

All who knew Fox-Strangways were charmed with his gentleness and modesty. A remarkably steady, systematic, untiring, and persistent worker, he covered his ground in the field with singular thoroughness, and his maps probably contain as much careful and conscientious record of fact as those produced by any Survey Officer. His charming disposition and unruffled demeanour endeared him to all who had the privilege of enjoying his hospitality or of accompanying him into the field. But this was combined with a modest reserve which it was most difficult to break down, and there were very few who could feel that they knew him intimately. Those he trusted he trusted absolutely. In his quiet, persevering way he got through a very great amount of work, most of which he succeeded in finishing; and it is by such men as he was that some of the best of the world's work is done.

ARTHUR HENRY STOKES was born in 1842, became a mining engineer and colliery-manager in the Staffordshire and Derbyshire coalfields, and explored and reported upon coalfields in Sweden.

He was appointed an Inspector of Mines in 1874, and was promoted to be Chief Inspector in the Midland District in 1887. During this period he on several occasions performed acts of great bravery in the rescue of men entombed in mines. In 1879 the Silver Medal of the Order of St. John of Jerusalem was awarded to him, and in 1882 the Albert Medal of the First Class. He joined this Society in 1874, and in 1880 published his only paper in the Quarterly Journal, 'On the Coal found at Süderöe in the Faröe Islands.' He made numerous important contributions to mining journals on lead-mining, safety-lamps, and economic geology, and wrote a history and geology of Castleton. He died at Derby on November 10th, 1910, in his 68th year.

William Phipps Blake was born in New York on June 1st, 1826, and received his scientific education at the University of Yale, from which he graduated in 1852, among his co-graduates being Prof. Brush and Prof. Brewer. From 1854 to 1856 he acted as Geologist and Mineralogist on the explorations for the proposed Pacific Railway, reaching California shortly after the discovery of gold there. He carried on mining explorations in North Carolina and Georgia in 1860, and from 1861 to 1863 was employed by the Imperial Government of Japan in an examination of the mineral resources of that country. He also visited Alaska in 1867. In 1864 he became Professor of Geology and Mineralogy in the College of California, and, later, he was appointed Professor of Geology and Director of the School of Mines at the University of Arizona, being made Emeritus Professor in 1895. He was also, for some years, Territorial Geologist of Arizona.

He joined the Geological Society in 1876, and remained a Fellow until his death on May 22nd, 1910. His earlier papers were devoted to mineralogy, a subject in which he maintained his interest up to the end of his life. Other subjects on which he wrote comprise infusorial earths; deserts and the action of the sand-blast; the mammoth, tapir, *Hipparion*, and other mammals; the ores of gold, silver, iron, mercury, and tin; the Rocky Mountains, California, Arizona, Oregon, and Wisconsin; coal, glaciation, earthquakes, and oscillations of level; and he even contributed a paper on the Pliocene skull of California. He was also the author of a volume on 'The Production of the Precious Metals'.[1]

---

[1] Taken in part from Am. Journ. Sci. ser. 4, vol. xxx (1910) pp. 95-96.

The Rev. GEORGE FERRIS WHIDBORNE was descended from Sir Richard Whidborne, one of the Devonians who provided ships to fight the Spanish Armada, and a founder of the Colony of Newfoundland. He was born in 1846, and died somewhat suddenly on February 14th, 1910, in the 64th year of his age. My first duty as incoming President of the Society was to attend his funeral at his beautiful house at Hammerwood, in the heart of the Weald. He joined the Society in 1876, and several times served on its Council and on the Council of the Palæontographical Society. He contributed papers on Inferior Oolite fossils and on the geographical distribution of the Plesiosaurs to the Quarterly Journal; printed lists of Devonian fossils, largely from his own collection, in the Proceedings of the Geologists' Association; described fossils of Lower Devonian if not Silurian affinities from the Morte Slates for Dr. H. Hicks; and published papers dealing mainly with Devonian fossils in the 'Geological Magazine.' But his great geological work was contributed to the Palæontographical Society. At first he contented himself with sending numerous brachiopods from his collection to Thomas Davidson to deal with in his great Monograph. But, later, he was prevailed upon to undertake the description of the entire fauna of the Devonian Limestones and of the Marwood and Pilton Beds in a single monograph. This was published, and forms a complete work in three bulky volumes, the excellent illustrations of which were, many of them, contributed at his own expense.

Much of his life was occupied with hard and self-sacrificing labour on behalf of the National Church; but the only benefice he held was that of St. George's, Battersea, which he retained for eight years and resigned in 1896. He was connected with many Church Institutions, most of which profited by his open-handed generosity. He took an especial interest in the Church Missionary Society and the Victoria Institute. It was only a comparatively short time before his death that he bought his estate at Hammerwood and settled down in residence there. His valuable collection of geological specimens and his library have been presented by Mrs. Whidborne to the Sedgwick Museum at Cambridge. His death removes one whose companionship was most genial, who acted as a generous benefactor to several geological causes, a palæontologist of mark, and a man beloved by many friends.

THOMAS MUSGRAVE HEAPHY, who had become a Fellow of this Society in 1876, died on March 29th, 1910. He was for many years consulting electrical engineer to the Phœnix Fire Insurance

Company. He had volunteered in the early sixties in the cause of Italian liberation, and fought under Garibaldi. He rendered considerable service to the Society, by giving advice and supervising estimates, when electric light was installed in the Apartments at Burlington House in 1896.

CHARLES BIRD was born in January 1843. He was a graduate of the University of London, and, while Second Master at Bradford Grammar School, studied and wrote on the Red Beds at the base of the Carboniferous Limestone in the North-West of England. In 1881 he published 'A Short Sketch of the Geology of Yorkshire.' About this time he became Head Master of the Mathematical School in Rochester, and, while there, published an 'Elementary Geology' and an 'Advanced Geology.' He also published papers on local geology in the 'Rochester Naturalist,' and assisted in conducting excursions of the Geologists' Association. He was President of the Rochester Naturalists' Society for four years, between 1883 and 1889. He joined the Geological Society in 1882, and remained a Fellow until his death on April 11th, 1910, at the age of 67.

JOHN ROCHE DAKYNS was born in 1836 in the West Indies. He was educated at Rugby and at Trinity College, Cambridge, whence he graduated in the Mathematical Tripos. He joined the Geological Survey in 1862, and was promoted to the rank of Geologist in 1868. His chief work was in the Derbyshire and Yorkshire Coalfield, the Plain of York, the Pennine Chain, and the Eden Valley. In 1872 he read a paper to this Society on the Glacial Phenomena of the Yorkshire Uplands. He was transferred to the Scottish branch of the Survey in 1884, and in connexion with his work there he communicated his second paper to the Society, 'On the Plutonic Rocks of Garabal Hill & Meall Breac,' which was written in conjunction with Dr. Teall. His last two years of Survey work were spent in the South Wales Coalfield, and he retired in 1896 to Snowdon View, Beddgelert, where he occupied his leisure strenuously in mapping the greater part of Snowdon on the 6-inch scale. He died on September 27th, 1910, at the age of 75.

Although he never joined this Society, he communicated numerous papers to the 'Geological Magazine' and to the Yorkshire Societies, but his publications, even when those contained in maps and memoirs are added, by no means represent the large

amount of original work which he carried out. And even this latter does not give a true measure of his influence for the good of his science in his insistence on extreme closeness of observation and accuracy in reasoning.[1]

The chief geological event of the past year has been the holding of the Eleventh International Geological Congress at Stockholm. The Congress was attended by several Fellows of the Society, including the ex-President and the Treasurer. An extremely interesting and well-organised series of excursions was planned and carried out, the meetings were of considerable importance, and the event was further marked by the issue of valuable publications dealing with the geology of Sweden and with the distribution of iron-ores.

In our own Society the event of first importance has been the unanimous decision of a Special General Meeting to utilise the space now occupied by the Museum for an extension of the Library, and to offer the Society's collection of minerals, rocks, and fossils, with a few exceptions, to one or more of the National Museums of the country.

This is a welcome solution of the problem which has agitated the Fellows for many years. The accommodation provided by the Apartments is limited, and it is the duty of the Society to employ the space generously placed at its disposal by the Government in the way which will contribute most to the welfare of the Science. The collections occupy a great deal of space, even packed away as they now are. For their proper display much more space than can be given to them would be required, while they would need the constant care and attention of a curator, and the expenditure upon them of an amount of money which the Society could not afford without crippling seriously one or more of its other spheres of activity.

For many years after the Society was founded geological museums were scarce and difficult of access. It was at that time, therefore, clearly the duty of the Society, and its best service to geology, to offer an asylum to specimens of scientific value and importance, to form the nucleus of a great geological museum, and, at the same time, to afford to students and investigators facilities for the examination and comparison of specimens and types.

---

[1] Further particulars will be found in Geol. Mag. dec. 5, vol. vii (1910) p. 575; and in Proc. Yorks. Geol. Soc. vol. xvii (1910) p. 159.

But times have changed. There are great national museums, one of the duties of which is to contain and conserve collections of geological specimens, and to make them accessible to investigators; and there are teaching institutions at which students are provided with the geological material necessary for their studies. There is not, therefore, the pressing need that formerly existed for the Geological Society to maintain a museum of its own.

On the other hand, the Society has been gradually accumulating what is probably the finest collection of geological literature in the world. The Society's exchanges, its acknowledged position in the Science, and the sums devoted to the upkeep of the Library, combine to make the annual accumulation of books a very formidable matter, but one which redounds to the credit of the Society, adds to its reputation, and makes its Fellowship of great value to geological workers. The importance of the Library is further considerably enhanced by the annual publication of the list of additions to it in the form of 'Geological Literature.' The vast service that this Library renders and is capable of rendering to Geological Science makes it imperative that the Geological Society should foster its growth by every means in its power, should secure the presence in it of all works of importance, should catalogue them properly and continuously, and render them easily accessible to those who wish to consult them. This cannot be properly carried out in the room at present devoted to the Library, which has already overflowed into several other of the rooms in the House. An additional series of rooms, worthy of the object and suitably fitted up, is an absolute necessity if the Society is to do its duty by its Library. And the only rooms available are those at present devoted to the Museum.

It has, therefore, been thought well by the Society to pass the resolutions mentioned in the Annual Report, and to commit to the Council the task of drafting a scheme for the disposal of the contents of the Museum and of providing in their place for additional Library accommodation. The passing of that Annual Report by the Anniversary Meeting to-day may be regarded as confirming these resolutions.

The contents of the Collection have been given to the Society by a very large number of donors throughout the century of its existence. They consist in part of minerals, rocks, and fossils, illustrating papers read to the Society; in part of specimens collected by Fellows in their travels in Foreign countries and in the Colonies; and in part of material collected in the working out

of the geology of this country. The material has been given to the Society in the trust that the Society would make such use of it as would be of greatest benefit to the Science. Much of it is of high intrinsic value; but its scientific value to experts is far higher, for there are in it not less than 2000 types and figured specimens. It is, therefore, the documentary evidence of the advance of Geology in this country, and it is exceptionally precious on that account. It is clear that, as we have resolved, it ought only to go to one or more of the National Institutions.

Moreover, it must go with the proviso that it shall be readily accessible to those who are most capable of making good use of it—specialists in Geology, Palæontology, and Mineralogy. Its contents should not be scattered, but should be kept within the area of a single city. And it is extremely important that that city should be so situated as to be the most convenient possible to the numerous workers who will make use of the collection.

Considerations like these will doubtless be taken into account by the Council, in drawing up a scheme to be presented to the Society for its decision.

Geology as Geographical Evolution.

The broadest and most popular conception of 'Geology' is the 'History of the Earth.' And to a large extent this conception is justifiable, for it is to the elucidation of Earth History that all branches of the science are contributory, and from a knowledge and interpretation of the details of this history that the applications of Geology proceed.

The successive time-periods of much of that history have long since been broadly defined and their relative chronological order established by the study of the characters, sequence, and distribution, of the geological formations, and their grouping into those grander assemblages the Geological Systems.

In the Geological Record thus arrived at and universally accepted, one of the most striking and fundamental facts is the preservation in rocks of the relics of once-living animals and plants, and it was only natural that, immediately these objects were admitted to be of organic origin, they should be eagerly collected, classified, compared with modern forms and with one another, and arranged geologically in the order in which the rocks containing them were deposited.

As the result of more than a century's work upon fossils we are now well assured:—(1) That each Geological System is characterised by a distinct fauna or flora; (2) that each such fauna or flora is, on the whole, an improvement on that which preceded it; and (3) that the relation of a fauna or flora to its successor is of an ancestral character.

The numberless facts collected by geologists, and the inevitable conclusions towards which they point, admit of their simplest and most harmonious explanation on the theory of evolution, and, indeed, they have furnished by far the strongest evidence in favour of this doctrine. As yet they have not enabled us to discover the machinery by which the evolution of life was brought about, but we feel confident that on the chain of past life hangs the key both to the conflict between existing views and to those future advances in knowledge and opinion by which the mystery of evolution will be ultimately solved.

The year 1909—the jubilee of the 'Origin of Species' as well as the centenary of its author—was marked by important memoirs by Sir Archibald Geikie and Prof. Judd on the geological work of Darwin himself; while last year Prof. Judd showed that the broad and solid foundations on which Darwin built were laid for him by Scrope and Lyell.

(1) The Use of Geographical Parallels.

While the Geologist has been able to infer from the facts at his command, not only that an evolutionary chain of life has existed on the earth, but that in the past, as in the present, biological conditions of competition, food-supply, etc., have varied from time to time and from place to place, he has, in demonstrating the immense variations in physical environment that have taken place in geological time, made a third and at least equally important contribution to evolution. He has proved that the climate, the relative position of land and water, the height, the slope, and the very lithological composition, of the land have been in a state of perpetual flux from the earliest periods to the present.

This he has done by his acceptance and employment of the fundamental principle of uniformitarianism, that the present is the key to the past; by his careful comparison of the phenomena of the dead past with the results of the living processes of the present; by a study of the denudation and deposition, of earth-movement and vulcanicity, of the birth, and growth, and death of land-forms.

From these comparisons has arisen a general knowledge of the laws which govern the formation of rock-masses, their deformation in building up the earth-crust, the interaction of internal and external forces, the share of organic and inorganic agencies, the 'lapse of waves and the life of stones.'

It has often happened, however, that the application of a general principle on a far minuter scale than was contemplated by its founder has led on to a new development and to new results wholly undreamed of by him. This has been especially true of the method taught by the uniformitarians.

All British geologists must admit that they owe to Godwin-Austen and Ramsay such an 'intensive' application of uniformitarianism. They showed the interest appertaining to distinctive and exceptional phases of present-day physiography, when considered in relation to the abnormal characteristics of certain of the geological formations. They seem to have brought us nearer to a vivid visualisation of the past, they transformed stratigraphical into historical Geology, changed the formations from 'the cemeteries of once-living organisms' into a world pulsating with the teeming life of forgotten ages, a world in which we could see, as in a series of impressionist pictures, the lakes and mountains, the rivers and volcanoes of the past.

There were, of course, objectors who argued that no attempt to find a complete parallel between any particular local or regional phase of the past and a modern, existent, representative was likely to be successful in every detail; that the exact grouping of all the circumstances was not likely to recur at any one spot; that, at best, geographical parallels to explain past geological phases were only likely to be found by the comparison of several existing areas. All this may be freely admitted. Nevertheless the search gives a keener incentive for the minute examination of details by both Geologist and Geographer; a stimulation to the imagination to attempt the explanation of unsolved difficulties; a new impulse for the Geographer to prosecute more detailed research in areas already 'discovered and explained'; and a means for the expression of some of the results of our science in a language and imagery which are more likely to be understanded of the people than the terminological exactitudes in which we are accustomed to clothe our conclusions.

My belief is that the method is not by any means exhausted, and that with our growing knowledge of the surface of our earth on the one hand and of the rocks on the other, we may hope to advance

much farther in the interpretation of the physiography of the past. But our guide must be the union of delicate stratigraphical research with minute geographical work. We must be accurate in our geological facts; but we may, as Darwin advised us, speculate freely, and our lode-star should be the injunction to 'travel, travel, travel.'

(2) The Cycle of Earth-Movement.

The geological record of a single region such as Britain is a chronicle of two chief classes of events. On the one hand, the great masses of sediment record periods of downward movement, more or less interrupted, during which the area was covered by the sea or other widely extended waters; while, on the other, the physical breaks in sedimentation, and particularly the great unconformities, furnish us with evidence of uplift into the regions of denudation, mostly areas of land or relatively shallow water.

The study of the British record tells of many pulsations of movement, varying in direction and intensity, but each one accompanied, on the whole, by cycles of phenomena, similar in their march of events, but varied in other details by the external conditions under which they were developed.

(3) The Cycle of Deposition.

The general succession is approximately as follows:—

(i) A deeper-water or 'thalassic' period, with widespread, even-bedded, fine-grained, seaward, sediments, succeeding or alternating with organic deposits.

(ii) A shallower-water period, with 'deltaic' and littoral, shoreward, deposits of mudstones and sandstones more limited in their distribution, but laid down on smooth areas, associated with phenomena of contemporaneous erosion and overlap, with increasing coarseness of grain and with decreasing numbers of organic remains.

(iii) A period of rising and uplift giving origin to continents, mountains, and lakes, to rapid denudation filling the hollows thus formed with irregular masses of coarse-grained, 'terrestrial,' landward, deposits which are variable in their composition and source, difficult to correlate, characteristically poor in organisms, and frequently associated with sheets or masses of locally derived and angular or slightly rounded materials.

(iv) A period of sinking and depression, during which the sea

gradually obtains ingress to the lower lands and lake-areas, converting them into gulfs and estuaries, and lays down in them sheets of shoreward but 'estuarine' deposits, smooth and flat over the deposits of the preceding period, and made of débris provided by the continued activity of the agents of erosion. But, owing to the irregular contour of the drowning land, every sheet so laid down will be of irregular shape, each one will pass at its edges into coastal deposits, and each will transgress during the submergence with increasing overlap beyond the preceding deposit and against the old land until that old land is at length completely lost under the sea.

(v) Finally, the old land sinks completely under the sea, deeper-water ('thalassic') conditions recur, and the cycle is complete.

(4) Difficulties and Exceptions.

While the normal succession of events in a cycle of deposition will be that just described, normal stratigraphical phenomena by no means always obtain. For example:—

(*a*) The uplift may be of epeirogenic rather than orogenic type; the sediments may not be much disturbed in their lie, and denudation may be content only to strip off the upper portion of recently formed deposits. Unconformity will be slight, the break in sedimentation inconsiderable, and the newly formed sediments not strikingly different from those which precede them.

(*b*) The uplift, if orogenic, may be of such long duration that an entire cycle of denudation is completed and the land-forms smoothed down to a peneplain, so that the newer sediments become laid down on an approximately level, plain-like, surface of older rock-formations, the strata of which will, however, be separated from those of the new-made formations by flagrant unconformity.

(5) Details.

In our own country excellent examples of the normal progression and the normally associated phenomena are usually detected, as well as examples of the two variants just noted. Of the normal sequence, the progression from the time of deposition of the Carboniferous Limestone through the time of the Pennine-Armorican movement into Middle Jurassic time may be regarded as quite typical, but numerous other examples will at once suggest themselves. We may consider the normal succession in a little fuller detail.

(*a*) 'Thalassic Period.'

(1) So long as deeper-water ('thalassic') deposition is taking place, the extent and depth of water is sufficient to allow of the wide dispersal of sediment before it finally reaches and subsides upon the sea-floor, and hence the areas of similar sediment deposited will be wide. This is abundantly proved by soundings. In these circumstances each lamina in such a deposit must answer to a single sea-floor, and be approximately contemporaneous throughout its entire horizontal extent. These laminæ will, therefore, correspond with time-planes. Their outer margins will, however, grade into organic, and their inner margins into coarse sedimentary, deposits. In the deposits of the outer margins correlation by organisms, if carried progressively from point to point, ought not to present very serious difficulties.

Whether any evidences of still more profound ocean-depths, in the form of oceanic or abysmal deposits, occur among British strata has been a subject of considerable discussion. For a reason to be stated later, such deposits are not to be expected on an extensive scale in Britain. It has been maintained that some of the radiolarian cherts are not truly abysmal deposits, but it is noteworthy that these rocks are practically free from terrigenous material.

(*b*) 'Deltaic Period.'

(2) As uplift proceeds it not only elevates the land but brings the floor of the area of deposition nearer to the surface of the sea. Denudation becomes more active, and the amount of coarse detritus carried out and deposited in shallow water increases in quantity. Serious mistakes in correlation must inevitably result if the 'strata' thus laid down are interpreted in the same way as in a deeper-water deposit. We know of no means by which sand can be spread out under water simultaneously over large areas, so as to form a sheet contemporaneous throughout. Even during the depression of the estuarine phase, while the area is expanding, the deposit will grow landwards and gradually envelop the submerged land-form; thus the inner or landward parts will be the newer. During uplift, again, when the area of deposition is contracting, two things will occur:—(i) The deposit will travel outwards and seawards from its margin, and the outer parts will be the newest; (ii) those portions of the deposit nearest land, and therefore the first to feel the uplift, will be subject to denudation, and will be partly broken up and redistributed as a new deposit farther out to sea.

Since the thickest part of such an accumulation is, from the nature of the case, the part most liable to destruction, it must follow that the thickest parts of stratified masses now preserved do not afford unequivocal evidence of the exact position of sea-margins. The phenomena of aggregation and erosion under the conditions postulated explain for us the lenticular deposition and the amount of contemporaneous erosion which characterise such sediments as those parts of the Silurian rocks that were formed during periods of uplift. These characteristics have been brought out by the researches of Dr. Herbert Lapworth in Central Wales and by Miss Elles and Mrs. Shakespear on the Welsh Border.

In view of the fact that planes along which occur the sediments actually deposited in one and the same limited period of geological time—true time-planes, as contrasted with theoretical or conventional time-planes—must cut through many kinds of sediments in deposits formed under these circumstances, it is evident that they will not be throughout strictly coincident with the lithological divisions known as stratification. It is, therefore, necessary from time to time to re-examine any of the bases of our correlation in which shallow-water deposits may be concerned. Thus, in tracing the variations of the Lower Oolites from the Cotswolds into Lincolnshire and Yorkshire, a most useful summit-line has been found and utilised in the Cornbrash, which is continuous in its presence and characters from one end of the country to the other. But it is improbable that this Cornbrash formation, one of typical shallow-water aspect, could by any possibility have been deposited contemporaneously throughout the whole of this area. It has served an important stratigraphical purpose in initiating correlation; but the formation itself must almost of necessity be progressively older when traced in one direction or another throughout its extent. Unfortunately, J. F. Blake did not live to express the conclusions to which his study of the Cornbrash fauna was leading him.

(*c*) 'Terrestrial Period.'

(3) While uplift is in progress, the tectonic structures that are being produced will be submitted to the denuding action of the sea, which is likely to give to the whole smooth, plane-like, outlines. But, so soon as there is emergence, the denuding agencies will begin to adjust themselves to the growing structures, and diversity in relief will be the consequence. The deposits now formed will tend to accommodate themselves to this relief. For brevity, they are here designated 'terrestrial deposits.'

Whatever irregularities there may have been in the accumulation of the shallow-water deposits of the preceding phase, they will be intensified in the terrestrial deposits which are laid down in this succeeding phase of uplift, and they will be correspondingly difficult to correlate and arrange in order of time. Screes and gravels—the result of frost and torrent action, and even sands formed in the air, must necessarily be pushed outwards from their sites of origin; and if, during this outward migration, sheets of such materials originate, it is clear that the different parts of any one of them must be of different dates.

To a smaller extent the same is true of lacustrine deposits, and there must be an outward progression from the shores towards the deeper parts of these water-holding basins.

The materials deposited during the phase of uplift show a tendency towards one of two extremes; they are characterised either by their angularity, or by the great amount of corrasion which they have undergone. Débris broken up in the air, whether accumulating in air or water, whether carried directly by gravitation, by land-slips, or by ice, tends to retain its sharply broken edges. But water-transported matter carried by high-velocity streams becomes exceptionally well-rounded, and material fine enough to be carried by wind becomes smoothed and polished.

Prof. Charles Lapworth has drawn attention to the fact that one of the physiographical results of orogenic movement, accompanied by denudation, is the tendency to intensify the production of longitudinal valleys. There is observable in the Alps, and probably elsewhere, a similar connexion between earth-movement and the formation of breccias. Excessive formation of screes and landslips is found to be associated with the outcrop of thrust-planes. In the quickened denudation brought about by the steep slopes thus maintained there may possibly be found one explanation of the frequent association of breccias with mountain-building.

Torrent-formed gravels are shot down immediately at the foot of mountain-land, whether this abuts on sheets of water or on areas of flat sediment recently formed or newly lifted. The first-formed mass of gravel alters the conditions of slope and velocity, and successive loads are carried farther and farther outwards until they reach gentler slopes or stiller water, and are perforce deposited there. Thus the mass grows outwards from the area of denudation, each increment being laid down against the preceding one on the surfaces that we know as planes of 'false bedding.' These planes are, therefore, the true 'time-planes' of contemporaneous deposit

in the mass, and they must necessarily make an angle with the upper and lower surfaces of the mass as a whole when its formation is completed.

Neither the upper nor the lower surface of the 'bed' so formed will be a true time-plane. Its lower surface will be in contact with the floor on to which the deposit has been pushed outwards, and, therefore, will be of decreasing antiquity when followed outwards from the area of denudation. As the 'floor' may be receiving fine-grained deposit (for instance, air-borne or laid down in a lake), portions of this finer-grained deposit will be contemporaneous with parts of the pebble-deposit. Thus the 'time-planes' will pass down through the pebble-deposit into the finer-grained 'bed' beneath. On the other hand, the top of the 'bed' is conditioned by slope and stream-velocity; and, where pebble-deposit ceases at any point, it may be succeeded there by the laying down of fine-grained material (except along the actual stream-courses), each part of which, in its turn, will be synchronous with some part of the pebble-deposit on the outer margins. The 'time-planes' will, therefore, here pass up into the overlying fine-grained deposit.

Thus, while it may be convenient to map such masses of pebble-'beds' as single units, and even to think of them as individual 'formations,' erroneous conclusions will inevitably follow unless it is clearly realised that they are, in the main, units of structure, texture, and condition, rather than of time. In converting the record yielded by them into terms of time, it is essential in most cases to ascertain their exact conditions of formation, and to be guided by these in interpreting their structures and relationships.

From the variable and intensely localised conditions which determine the accumulation of 'terrestrial' deposits, it must follow that formations originating thus will be lenticular and irregular in their distribution, while means of correlation by organisms will be of the scantiest and the most unsatisfactory nature. Breccias formed by weather-action, or by glaciers in one part of the area, may be contemporaneous with pebble-beds, gravels, and alluvia in another, with lacustrine sediments or even with wind-drifted sands or lœss elsewhere. Delicate correlation in the case of such deposits as those to which I have just alluded will probably always be a matter of no little difficulty.

In connexion with these deposits, it is instructive to study not only the work of W. T. Blanford and Sir Arthur McMahon in Central Asia, but to consult also the more recent work of Mr. W. R. Rickmers in that region.

If it should happen that the lines of maximum uplift have been so situated as to cut off rain-bearing winds from the lower-lying lands, so that desert conditions arise, then denudation due to insolation and frost will be so rapid—compared with chemical action—that there will be little decomposition of the more stable minerals. Only the more soluble ingredients will be removed from the minerals most easily broken down, and the detritus mechanically transported will consist of fresh and unweathered minerals. This has been well demonstrated by the observations of Prof. Judd on the Nile muds, and by those of Dickson and Holland on the glacial muds of the Alps. It has also been found that the coarser detritus in such deposits as the Triassic skerries formed round the wind-smoothed rocks of Mountsorrel and other Leicestershire areas is in a precisely similar condition.

At the same time, the salts that are dissolved are often not carried outside the area of inland drainage, but are deposited in the lakes and pools, or thrown down as crusts upon, or cements among, the materials of the drier areas. The latter must often take place where the water-bodies have outlets which lose themselves in the sandy and desert areas. It is possible that the dolomite crystals found by Dr. Cullis and Mr. Bosworth in the Keuper Marls may, in part, have some such origin.

(*d*) 'Estuarine Period.'

(4) There will, as a rule, be a sharp contrast between the features produced when uplift is taking place, and those which are in existence when re-submergence follows the terrestrial phase. The tectonic structures that are being formed are all submitted to the rasping action of marine erosion as they rise; and the emergent land consists in part of planed folds, and in part of flat or gently inclined sediments. But during the terrestrial phase the rock-structures are dissected by subaërial denudation, originating features of lively relief which, on submergence, will cause corresponding diversity of contour. The rising coast will be one of sea-flats and deltas, the subsiding coast one of gulfs and estuaries.

Flat areas of completed erosion and planes of lacustrine, desert, or lœss, deposition will, on submergence, be the first to receive new sediments. The edges of these deposits will creep up to the uneroded mountain framework, and will pass rapidly into shallow-water and marginal sediments. As submergence proceeds there will be rapid overlap of coarser by finer material, each sheet of which will, however, be edged by its coastal representative. Such

coastal deposits furnish us with the most precise data that we possess concerning the physical changes of the period of subsidence, and it is very unfortunate that it is just this class of deposits which is most susceptible to destruction and removal later in its history.

When, after partial or complete submergence, old high lands have again become resistant high land, there is a great tendency for streams to grow between them and their enwrapping sediments. It is here that the marginal and coastal types of sediment will occur, and hence there will be considerable risk of their ultimate destruction and disappearance. The Severn, the Dee, the Ouse, and the Trent have robbed us of many valuable data which might have given us better knowledge of the local geography throughout the whole of Mesozoic times. But fortunate chances in the Mendips and South Wales, in Devon and the Eden Valley, in parts of Shropshire and in Charnwood Forest, have left precious relics of marginal deposits of many ages, from Llandovery up to Cretaceous times. At these isolated spots the facts enable us to extend in imagination the margins of Mesozoic and earlier seas against the older land-masses, and allow us to assure ourselves that the science of palæogeography is not so hopeless as some would have us believe. We have the old pebble-beaches, the screes, the cavern and fissure-deposits, the washed-off vegetation and land-dwellers, and, in certain cases, of which those already discovered are perhaps only a foretaste, considerable areas of the enveloped landscapes.

In the case of old high lands, which after complete burial have failed to re-emerge from their enveloping sediments, more continuous evidence is in existence; though, from the nature of the case, it is more rarely recoverable. Our knowledge in such cases is limited to facts collected from borings and to inferences drawn from the conditions of exposed deposits earlier or later in date. Of the former our growing knowledge of the Armorican massif is an excellent type; while of the latter Prof. Kendall's utilisation of the variation and the relations of the Jurassic and Cretaceous sediments of the Eastern Midlands to infer the extension and continued instability of the Charnian axis is a brilliant example.

(*e*) 'Thalassic Period.'

(5) The deposits of a 'thalassic' period succeeding a period of uplift demand only passing notice. The successive encroachments of the sea bring an increasing proportion of fine-grained and organic deposits, with partial and (it may be) complete envelopment of the old land-areas.

(6) Examples.

The simple and stately progression of events thus outlined, from depression to uplift and back again to depression, can rarely be exemplified in completeness from the succession of British Formations. There are necessarily many checks, variations in the rate of movement, and alterations in both rate and type of deposition. Thus, a movement of subsidence or of elevation has rarely been uninterrupted by pauses, or even by reversal of movement. The great Caledonian movement had at least three periods of high intensity, with pauses and reversals. The movement was at times so slow that it was overtaken by deposition, while at other times deposits were swamped by its rapidity. Besides this, as has been frequently pointed out, certain classes of the deposits are especially liable to destruction during submergence or emergence. When to this is added the possible influence of isostasy, allowing the rapidly denuded land to rise and the heavily loaded sea-bed to sink, the results of any particular geographical phase become hard to follow and to link into a connected scheme.

We may perhaps trace in the Coal Measures the influence of the last-named cause. Although the story of the Carboniferous Period is one of the shallowing of an area by upward movement, there are facts which are best explained by occasional reversal. If we accept the 'growth *in sitû*' theory of coal-seams, this contention needs no further support, for the entire history of these strata would be explicable by slow irregular subsidence, accompanied by deposition sufficiently rapid to fill the hollows as fast or nearly as fast as they were formed; while the coal-seams would be explicable as the results of prolonged pauses in the general downward motion. Even if we do not accept the theory of growth *in sitû*, the overlap in Britain of the Lower by the Upper Coal Measures is evidence of an area of deposit temporarily expanding. That the movement was not quite a simple one, however, but was accompanied by considerable folding of the older Coal Measures, has been abundantly proved by Mr. W. F. Clark in his new interpretation of the 'Symon Fault' of the Coalbrookdale Coalfield. In a paper published in our Journal he has shown that this phenomenon is not due to an eroded valley as supposed by Scott, but to the planation of a series of asymmetrical folds, on the denuded edges of which the newer Coal Measures were subsequently laid down.

In our applications of Physiography to Geology we are not

necessarily confined to dealing with statical conditions. We may make use of our knowledge of the progression of events likely to follow during the normal geographical development of the area of our study, to institute comparisons with the events recorded in a continuous succession of stratified rocks. For example, I have personally found my ideas of Carboniferous conditions clarified after searching for like conditions or succession of conditions in the present.

The Gulf of Mexico, with the Mississippi delta, the island of Cuba, and the Caribbean Sea beyond, may be used to focus our ideas on a possible succession of events not unlike the progress of affairs during the Carboniferous Period. At the present time the region may be said to be passing through a Carboniferous Limestone phase. We have (*a*) a great northern river with its delta, (*b*) a central sea, (*c*) an island to compare with the lowering 'Mercian Highlands,' and (*d*) the great 'Culm' depths of the Caribbean Sea. Conditions at present favour the deposit of organic material over vast areas in the region, the chief sediment coming in from the Mississippi and building there a delta under conditions very similar to those that prevailed when the Lower Carboniferous rocks of the Scottish and Northern Pennine areas were being laid down.

Supposing that the geography of the region were to remain as at present, or if events were to be hastened by a general uplift of the area, we should have a progression of phenomena not altogether unlike those recorded in the Carboniferous strata of Britain, that is, the gradual pushing out of the deltaic Coal-Measure conditions from the northern continent and from the 'Mercian' island. Everywhere the deltaic conditions will be preceded by a marine sediment of the type of the Millstone Grit; and, where conditions favour it, the actual Coal-Measure conditions may be locally foreshadowed in this deposit. The 'Millstone Grit' type of formation will be homotaxial throughout, it will represent the persistence of a condition, it will rest everywhere upon organic deposits, and will in turn be succeeded by deltaic Coal Measures. But neither it nor any member of the Coal-Measure sequence, except perhaps the coal-seams themselves, will be, as a whole, a true time-unit; in some places it will be of the same age as part of the organic deposits, in other places it will be contemporaneous with the formation of parts of the Coal Measures.

Another example may be drawn from the known progression from the Ordovician to the Old Red Sandstone. The British Ordovician geography finds its nearest modern parallel in the

'Festoon Islands' of the Western Pacific, with their active volcanoes, their steep slopes and profound depths, their sheltered and land-locked seas. The different types of Ordovician strata and volcanic rocks may be matched in the deposits which are now forming there. The continuance of upward movement in the Festoon Island region of the present would produce in the first instance 'mediterranean' seas of Silurian type, and, ultimately, land-locked lakes similar to those in which the Old Red Sandstone originated. Some of the boundaries of the lakes, like those of the Old Red Sandstone lakes, would have the structures of newly-developed orogenic units; while others would consist of older land-masses which have been modified to a smaller extent by the new movement.

I do not put forward these instances as perfect analogies, but I do believe that the imagination is stimulated by such comparisons, and that if one tries to visualise existing circumstances more thoroughly, one is more likely to look out for points of resemblance and difference between the present and the past, and to observe with greater acumen, or to criticise more unsparingly, the facts which such important and interesting rock-systems as these present for our observation. It will, of course, only be after the study and rejection of a number of instances that anything like satisfactory comparisons will be effected; and in nearly all instances we shall only reach a complete mental picture by combining conditions from many different areas. But the success that has so far rewarded this method affords encouragement in the task of examination and selection, and gives us reason to hope that the study of existing physiography and physiographical causes will prove in the future, as in the past, the master-key with which to unlock the secrets which Geology still holds for us.

(7) Need for New Geographical Work.

It is in coin of this denomination that the Geologist looks to the Geographer to repay part of his debt to Geology. Our science has given to Geography much to which its recent progress is due. The structure of the rock-masses of which land-forms are built up, the adjustment of denuding agencies to that structure, the existence in the past of causes now no longer in operation, and of alien structures, long since removed, but the influence of which may still be traced; all these and many other aids have been given to Geographers in their attempt to explain land-forms.

If the Geographer wishes to repay some of this debt, it may be suggested to him that we, for our part, require far more detailed observations on such results of particular geographical phases, under varying climates and in different parts of the world, as are likely to throw light on the method of formation of the rocks. But neither the observations made nor the record of them are likely to reach the utmost possible value to the Geologist, unless the Geographical observer possesses a practical knowledge of the actual difficulties which confront the Geologist. The observer in deserts should be equipped with some knowledge of those strata which by some are supposed to have been formed under desert conditions, so that he may be on the look-out for points of resemblance or dissimilarity. The observer of volcanoes will be of far more use to us if he knows something of the nature and position of contemporaneous and intrusive rocks, as laid bare in some of our great areas of dissected volcanic groups. The estimation of the denuding action and other work of the British rivers now being carried out by the research department of the Royal Geographical Society is a good illustration of the type of work desired.

To the Oceanographer and the marvellous work accomplished by him during the latter half of the last century, we are deeply in debt. He has discovered vast areas of slow deposit of previously unexpected materials in the profound depths of the ocean, and quickened us in our search for truly abysmal deposits among the strata. But we would now ask him for much more detailed observations of those prosaic terrigenous sediments which line our shores and compare so closely with the deposits that make up the bulk of the geological record. The great value of the results obtained from the Funafuti borings, not half of which have yet been fully utilised by geologists, give some inkling of what may reasonably be expected when geographical observers with a geological grounding are able to make a detailed study of the shallower-water deposits that everywhere fringe the land-areas.

(8) Palæogeography.

While we owe to Ramsay the most striking of the early attempts to picture for us certain of our phases of palæogeography, it was Clifton Ward and Prof. E. Hull who endeavoured to express the facts with regard to British deposits upon maps. They have been followed by Mr. A. J. Jukes-Browne, whose work on 'The Building of the British Isles' has been of great service in making it possible

to visualise and remember the leading phenomena of stratigraphical geology, and to group together numbers of facts and inferences with which it was previously most difficult to retain touch. But this is not all that we owe to the authors and followers of the method. Such maps systematise future research, they direct us to the places where the discovery of new facts is desirable, and they enable each new fact to be utilised in checking, establishing, or modifying, conclusions expressed by provisional lines on the maps.

It was only natural that this branch should advance with rapid strides in Britain, because this country has done so much detailed work, not only in the study of its own constituent formations, but also in the mapping of their extent of outcrop. There are other reasons also of which we should not lose sight.

(*a*) Methods of Investigation.

In order to obtain what Dr. Marr has called the 'geogram' of a formation in its greatest perfection, we require to know the entire extent of its variations, not only along its outcrop, but in that part which is hidden from sight; and we ought to be in a position to infer the probable variations in that almost equally important part which has been destroyed by denudation.

The study of the outcrop has in many cases proved of great service—because important variations, such as those of the Lower Jurassic rocks, have been detected and worked out along the line of strike. But the outcrop evidence decreases in value whenever it happens that denudation has left, as in the case of the Chalk, an outcrop which follows a condition line or condition strip of the area of deposition.

It is here that, in my opinion, insufficient use has been made of the 'isodiametric lines' which Prof. Hull drew attention to, and utilised to bring out the south-eastward thinning of the Mesozoic rocks. We look to the projected Memoir of the Geological Survey on the thickness of the British formations, which Fox-Strangways began and Mr. T. V. Holmes is carrying on, to give us information whereby it may be possible to draw such lines throughout the British strata. We may be able to deduce from such lines not only much information with regard to the laws of distribution of ancient sediments, with consequent inferences on their sources and boundaries, but also some indication of the nature and extent of ancient denudation. It is even possible that the lines may be found to bear relationships with contemporaneous sagging and

elevation, and with tectonic structures and movements subsequently produced, and thence even with lines of drainage.

Information on the buried extension of strata is more difficult to obtain, and it can only be got when folds or faults have broken the course of the regular structure, allowing the agents of denudation to lay bare a far larger sequence of formations than usual, or where deep drilling has been carried out. There is perhaps hardly a single deep boring in the country which has not yielded important information as to the variation of some stratum or other in a direction not coincident with its outcrop. Evidence is given of the thinning and disappearance of strata, of their change in grain, in organisms, and in relation to beds above and below. Whether these borings succeed or fail in their primary economic purpose, their value to the geologist is incalculable; and I would again urge, as on more than one previous occasion, that the information which they give should be preserved with the most jealous care. Not only detailed and tabulated records, but actual rock-specimens should be collected and kept; and, even though the information yielded may have in some cases to be locked up in confidence for a generation or more, that information will eventually be available for generalization. The confidence engendered by the administration and personnel of the Geological Survey has, I am glad to say, borne abundant fruit in this direction, and we may trust that an increasing flow of records of this invaluable information will continue to be stored in the Survey Office for the use of present and future geologists. It is even to be hoped that at some future time, both for economic and for purely scientific reasons, borings may be carried out at carefully selected spots, not only to elucidate underground structure and its bearings upon the distribution of deposits of economic value, but even to settle doubtful points of scientific interpretation.

The part of any formation which extends and is hidden beneath the sea presents even greater difficulties, and it is improbable that we shall ever possess more than inferential information about the large area of the earth's surface covered by the hydrosphere. It is true that lines of borings have been carried out across narrow and shallow seas, and a daring success was made of the lagoon-boring at Funafuti; but for the most part we shall have to obtain our knowledge of the origin and history of the greater features of the earth from observations made upon what are land-masses at the present time. Still, portions of areas which were until recently covered by the sea, but the surfaces of which have been raised above its level by deposits of drift, ice, coral, or other recent marine deposits,

present inviting spots for deep borings, if funds could be found for carrying them out, not only for economic but for strictly scientific reasons. Thus, borings in the north of the Isle of Man, made in search of salt-deposits, have revealed what was, until Pleistocene times, part of the bed of the Irish Sea; and we can hardly avoid speculating as to what would have been found if it had been practicable to carry down the Funafuti boring twice as far as was possible under the circumstances.

A consideration of the fact that each formation has been derived from, and implies the destruction of, an equal mass of pre-existing formations makes it evident that much of what would have been extremely valuable in giving evidence of palæogeography has been irrecoverably destroyed. Beyond the average line of outcrop of each formation we only have left occasional fortunate extensions of it, or just the stranded outliers which happen to have escaped destruction. In the absence of these we are driven to do our best with bits broken from the edges of the formations, which may chance to have been embedded in later rocks and to be still recognisable.

In default of other evidence, we may be guided by the principle that parallelism in the bedding of closely associated strata implies that any movement which may have occurred during their deposition has been of an epeirogenic character. There may have been advance or retreat of coast-lines, but no development of striking new structures. The physiographic features will remain approximately parallel to one another during the time and at the place represented by a series of conformable deposits. It is on this assumption that we are able to draw inferences as to the probable position and trend of the shore-lines of the Liassic Sea, based on our knowledge of the extension of the Trias on the one hand and of the Lower Oolites on the other.

(*b*) Growth of Britain.

From fragments of evidence like this, hammered out bit by bit by himself or by many other observers, Mr. Jukes-Browne has made a brave struggle to picture for us the stages of geography through which Britain has advanced to its present configuration, its successive 'lines of growth,' and the normal and critical periods of its evolution.

That so much success has rewarded the attempt is to some extent due to the nature of the area chosen. Britain, though at the present time the north-western outpost of the European continent, has not

received the sediments that build up its formations from that continent. It has, on the other hand, grown in the main south-eastwards since Palæozoic times, from the more ancient Laurentian land-mass on the west. What may have been the original extent, composition, or outline, of this land-mass we do not and perhaps can never know for certain; but it seems to have begun to undergo denudation in Torridonian times, and to have been gradually disintegrated until a mere wreck in the north-west of our Islands is all that is now left of it. Wave after wave of movement from the eastward has broken against the old continent, or off its edge, shore-line after shore-line has formed farther and farther eastwards: the present great northern plain of Europe representing the deeper sea into which the finer sediments were swept. Thus in Britain the deeper-water and finer-grained sediments are the least common, and the lithological facies of our formations is mostly coarse-grained, shallow, shoreward, and even terrestrial. This it is which has invested them with so much of exceptional interest, and has stimulated among British Geologists the practice of reasoning in the direction of palæogeography.

Innumerable oscillations and even great orogenic movements have occurred, varying the monotony of formational succession, but it was long before the western land was completely broken down, the newer features formed out of the relics of its earlier denudations acting in a sense as groynes on which the destructive forces were spent. The Caledonian movement first drew off the forces of marine attack, denudation being mainly concentrated on the newly formed and highly ridged mountains. Then followed the Pennine and Armorican movements with corresponding effects, and, finally, such minor elevations and dislocations as are due to the almost spent force of the Alpine disturbance drove the forces of the attack still farther to the east.

(*c*) Movement and Infilling.

While, when acting on rocks which have not been affected by previous movements, each distinct crust-movement in Britain has imposed its own definite direction or directions, in other cases the direction of older movements has been taken up again in the newer rocks. Thus the strikes of the Carboniferous rocks of the Pennine and Armorican regions are those of the trend of the local axes of elevation characteristic of those movements. But the strikes of those caught in the Central Valley of Scotland, in the Vale of Clwyd,

or in the Warwickshire Coalfield have been influenced by older directions. In the same way the Charnian direction of movement makes itself felt not only in the Cambrian rocks of Nuneaton, but also in the later Carboniferous rocks. Similarly, the Armorican direction has made itself felt in the Wealden Arch and in the London Basin.

The directions of movement are convincingly betrayed by the first infillings of terrestrial and lacustrine sediments which follow closely upon the movement. Very significant in this respect is the position of the main Torridonian outcrop. Still more definite is the evidence of the lines that border the Old Red Sandstone areas, of which enough is preserved, as shown by Sir Archibald Geikie, to give a fair idea of the position and outline of the lakes of this period. Almost equally striking is the run of the outcrops of the Permian and Triassic Systems, flanking the Pennine, running down to the Bristol Channel, and forming a tongue along the main syncline of North Devon.

The infillings of the New Red Sandstones, followed by the rest of the Mesozoic deposits, are particularly instructive. We find that they occur in three types of localities :—

(i) Flanking the features produced by the immediately preceding movements, and best preserved on the east side of them. Also in the minor synclines of those movements.

(ii) In the 'lee' area which often occurs between the rocks affected by the immediately preceding movement and the firm land of an earlier movement. The New Red Sandstones flanking the west of the Pennine and extending into the Irish Sea exemplify this position.

(iii) In the rejuvenated folds of still older rocks—for instance, in the vales of Eden, Dee, and Clwyd, in the rift-valley off Western Scotland, and in the Irish loughs such as Carlingford, Belfast, Larne, and Foyle.

The areas of deposition in our own islands thus tended to become increasingly complex as one movement succeeded another.

The study of the chief British movements makes it clear that in that region, at any rate, the distinction between orogenic and epeirogenic movement is a question rather of degree than of kind. The so-called 'orogenic' movements have been accompanied by sharper folding and faulting and the production of marked relief; the epeirogenic by the uplift of broad anticlinal curves, and by denudation over large areas of comparatively small thicknesses of sediment, and that for the most recently deposited. Among the typical orogenic

movements the chief are the earlier and later stages of those movements with Caledonian trend and that of post-Carboniferous times. Of epeirogenic may be noted the middle portion of the Caledonian movement, that in the late Carboniferous, that which closed the Jurassic Period, and that great uplift which came at the end of the Cretaceous.

But there were many gentle movements which we are only now beginning to appreciate, and doubtless many others of which we shall gain information later on by the application of the methods that have proved so successful in the hands of Mr. S. S. Buckman, Mr. L. Richardson, and others, in the study of the Jurassic rocks. In this case the minute zoning of the Bajocian rocks has shown clearly that the local thinning of the strata so frequent along the outcrop of the Inferior Oolite is correlated with the absence of particular faunas, and presumably of the strata which should contain them. This may be due to one of two main causes—(α) the absence of the strata owing to non-deposition or subsequent erosion, or (β) the migration and substitution of faunas. Exhaustive examination of the fossils indicates that the former explanation is more likely to be the satisfactory one; and that this is the case seems to me to be proved by the fact that at the junction-line, to which attention is called by minute zone-working, signs of erosion and of pause in deposition are usually visible in the form of irregular surfaces, borings by worms and mollusca, and by deposits of oysters or of rolled fragments and broken organisms. Further, the correlation of series of localities indicates progressive absence of increasing thicknesses of rock in definite directions. The directions thus indicated correspond with the position of minor folds in the subjacent or superjacent rocks. So there is every probability that these areas of erosion have been determined by slight but long-continued local uplift of anticlinal nature, affecting well-marked areas and culminating along definite lines.

Results apparently similar are coming out from the zoning work in Lower Carboniferous rocks, and it is interesting to compare these with the latest interpretation of the 'Symon Fault,' to which attention has already been directed. That such results do not yet appear to have been reached in the zoning of the Chalk may be partly due to the thickness of the zones into which that Formation is at present divided, or, which is more likely, to the Chalk having been formed under water so much deeper than most other British organic formations, that the elevatory movement was not sufficient to bring the area within the scope of denudation. On the other

hand, movement may have been in comparative abeyance during this part of the Cretaceous Period; but this is so unlikely that I am disposed to accept the second hypothesis.

If that explanation be the true one, we must look upon the Mesozoic as a period, not of rest, but of quiet epeirogenic movement of a pulsatory character. The evidence obtained from the 'non-sequences' in the Jurassic rocks would seem to indicate that the oolitic limestones were deposits of an exceptional nature in a sea which was clear, shallow, and favourable for life, rather than deep; and that the clays of this System were formed in deeper water than the alternating limestones. If this be the case, we are driven a stage farther back to some more remote explanation of those alternations which are so striking and tenacious a feature of the British strata between the Inferior Oolite and the Portland Beds. By what means was denudation so much quickened that even the deeper waters of the period of marine advance became loaded with fine-grained sediment over such wide areas? Was it merely the exposure at certain periods of material that was more easily denuded into fine mud; or is it not more likely that the climate may have varied periodically, and that denuding forces were correspondingly quickened and retarded?

(*d*) Recurrence of Type in Cycles of Deposition.

Marcel Bertrand, in a most suggestive and illuminating memoir, endeavoured to correlate the successive types of deposit preceding and following the movement periods of different dates with one another. In this he obtained considerable success, but in some instances, it seems to me, he rather strained the facts to bring them into conformity with his ideas of recurrence. Such recurrence is certainly traceable throughout the British record, but it is generally overlaid with differences so striking that the interference of other causes with a different periodicity must be suspected. This statement will become clearer when we examine a few examples and exceptions.

The remarkable resemblance of the sandy sediments of the Torridonian, the Old Red Sandstone, and the New Red Sandstone is a commonplace in British descriptive geology.

The Torridonian and Old Red Sandstone breccias, probably associated with maximum uplift, may be correlated with the Brockrams and the other Permian breccias.

The well-rounded pebble-beds of the Bunter constitute a type which we see anticipated in both Torridonian and Old Red Sandstone conglomerates, and followed to a certain extent by those of

the Lower Greensand, but more definitely by the Nagelfluh of the Alps.

The deltaic deposits of the Upper Carboniferous are copied by the Estuarine deposits of the Lower Oolites, and by both the Wealden and the Oligocene deposits, although it is not easy to point to any forerunners quite comparable with them.

The British Rhætic type of deposit is not altogether unlike the lowest Carboniferous in Scotland and the Upper Eocene in Southern England.

The Flysch of the European Alpine regions may be compared with the uppermost Silurian and with the problematical and difficult rocks of the Permo-Carboniferous.

The graptolitic shales of the Lower Palæozoic are to some extent copied by the clays of the Jurassic and Cretaceous.

(*e*) Variability and Non-Recurrence.

But in every case there are differences which go far to mask the primitive resemblances. The likeness is perhaps strongest in the Pebble-Beds with their exquisite rounding, their method of occurrence, and to some extent the nature of their material; but the Breccias differ in their massiveness, in the nature of the fragments contained in them, and in the relation of the latter to the rocks exposed to denudation at the time when they were formed. The Rhætic types of deposit vary in the smoothness and wide extent of the deposition areas, in the slowness or otherwise of the incursion of sea-water and marine organisms, and in the amount of oscillation which the area was undergoing. The Flysch-like deposits bridge over periods of movement of varying length, and form a barren type of deposit which encroaches upon different parts of one or more Systems. They differ from one another according to the duration and balance of conditions of shallow sedimentation ruled by uplift and contemporaneous erosion. The Red Beds may or may not be accompanied by deposits due to chemical reaction or precipitation. The Shales and Clays agree in the fineness of their sediment and in the presence of pelagic organisms; but they differ in consequence of the nature, depth, and extent of the great hollows of the sea-bed in which they were laid down—in some cases perhaps comparable with great ocean-depths, in others with those of smaller land-locked basins.

But the most profound difference is perhaps that seen between the Coal-bearing strata and any correlative deposits that may

occur in our area. These sandstones, shales, ganisters, fire-clays, bituminous shales, coals, cannels, and ironstones occur in Britain on two main levels in the Carboniferous rocks; but they are never repeated again on anything like the same scale in our British formations. The nearest approach to them is to be found in the Lower Oolites of Yorkshire; but there is, as it were, some slight attempt at recurrence also in the Tertiary rocks. More than this, it is a remarkable circumstance that more than half of the coals of the Northern Hemisphere are of Carboniferous age.

Croll, in associating the Glacial Epoch with astronomical causes and their influence on atmospheric circulation, has claimed that the physical configuration of the Atlantic Ocean may have had a secondary influence, in that by its peculiar outline it permitted of important variations in the oceanic circulation of the North Atlantic. Mr. A. R. Wallace has further pointed out that, coinciding with these conditions, there possibly occurred an elevation of North-Western Europe which may have allowed the land there to take advantage of the anomalous conditions of solar distance, axial direction, and oceanic circulation, to favour the accumulation of snow on the flanks of the North Atlantic Ocean. According to this suggested modification of the theory, the combination of several causes was required to bring about the remarkable phenomena of that most eventful epoch in our geological history.

It appears to me that a not less remarkable concatenation of events may have been required to produce a Carboniferous Period of the extent, duration, and importance of ours; a Period to which this country owes so much of its commercial and political pre-eminence. In the first place, there was required a wide area of sea gradually filling up with an unfailing supply of sediment brought by rivers of depth and power. It was further requisite that the sediments should be deposited with great regularity over the large area of a delta in wide flat sheets which seem, as though through isostatic conditions, to have been built up to the level of the sea, not once or twice but frequently, throughout fully the half of a great Geological Period. The deposition must have been accompanied by subsidence not regular but intermittent, with rest-intervals of sufficient length to allow of the growth of swamp vegetation for the varying but lengthy periods necessary for the accumulation of material sufficient to make seams of coal ranging from 2 to 30 feet in thickness. The vast area covered by some of these coal-seams has been compared with that of the forests on some of our modern tropical or sub-tropical swamps and deltas; but it must be confessed that no exact

present-day representative of the growth and preservation of carbonaceous matter on the scale of the Coal-Measures has yet been found. The nature of the vegetation must have been such that it could spread and flourish under the peculiar swamp conditions that prevailed, and yet be suitable to provide the class of material which would give origin to coaly matter. Last, but not least, the climate must have been such as to encourage rapid growth of rank vegetation; yet it must have allowed, in place of ordinary decay, a decomposition capable of permitting the storage of the numerous hydrocarbons which go to make up the coal.

Several of these conditions may have occurred more than once during geological ages in single localities and for short periods of time, and to this must be due the lignite seams of several of our formations. But the coincidence of them all and for the enormous period of time comprehended by the strata of our Coal-Measures is likely to be only a rare event; and it is remarkable that, during the Jurassic Period in Britain, there should be so near an approach to a recurrence of the conditions necessary to make a valuable coalfield.

The study of our British Coalfields seems to show that, even with the conditions so highly favourable as they were in our area, the most favourable conditions of all were concentrated in particular and limited regions. Tracing such a seam as the Thick Coal of South Staffordshire towards the border of its area of deposition, we find it rapidly passing into irregular and worthless carbonaceous sediment. Tracing it away from this line, we find it passing into its most concentrated and highly valuable condition. Beyond this, its constituent seams become divided and spread apart by the intervention of wedges of sediment which thicken out towards the north. Others of the coal-seams take on similar changes until, as Prof. Charles Lapworth pointed out in his valuable report to the Coal Commission, the coal-seams of North Staffordshire are contained in three or four times as much mechanical sediment as in the South Staffordshire Field.

In the same way, at approximately like distances from the southern land-barrier, the coal-seams of the Warwickshire Coalfield undergo a like change from south to north. Thus there would appear to occur, even in the regions of favourable sedimentation, a condition of things approximately parallel to the coast-line, capable of giving origin to a concentration of vegetable accumulation, correlated perhaps with less and more steady and regular movement than elsewhere. Mr. Wade has published evidence from the

Lancashire and Cheshire Coalfield which appears to point in the same direction.

I think that we may conclude from this example, which is typical of many, that cases of recurrence in our cycles of deposition are not likely to occur with frequency or exactness; but that under the complexity of causes which operate to impart to the strata their dominant characters there will probably be cases of reinforcement or interference which will give to each cycle, and each phase of a cycle, its individual characteristics.

Although in Britain we have cause to be grateful for a System like our Carboniferous, which provides us with so wide a range of products of economic value, we must acknowledge that our country has but an insignificant place in a table showing the world's distribution of native petroleum. But when we pass into the chief regions where petroleum is obtained, we must be struck by the restriction in its distribution. The problem of that distribution is complicated by the fact that, while coal remains stationary in the beds among which it was formed, petroleum can migrate, like water, from one formation to another; and the beds in which it is now stored may be separated considerably from those in which it originated. Even then, however, it tends to occur in rocks of rather restricted range. The constant association of petroleum, when indigenous in the rocks in which it now occurs, with the anomalous deposits which we associate with inland lakes and closed continental areas, gives a strong suggestion that the origin of petroleum is to be sought, not so much in special chemical reactions influencing chance organisms that may be preserved in rocks, as in a concurrence of the several special geographical conditions regulating the nature of the deposition and the existence and preservation of life-forms at certain phases of earth-history.

(9) Other Effects of Earth-Movement.

The intensity of the results of the successive movements gives the impression that it is related to their antiquity; but it is certain that intensity is, in reality, related to the distance of any part affected from the main focus of action. The folding, thrusting, and cleavage of the Charnian rocks and the disturbance and cleavage of those of the Longmynd appear to have been effected in pre-Cambrian times. In the latter case, the ring of Cambrian and later sediments remains unaffected by cleavage.

The more severe effects of the movements with Caledonian trend

spread outwards from the famous overthrust region of the North-West Highlands of Scotland, and the more central region marked by the recumbent folds recently described by Mr. Bailey. How much of the metamorphism is attributable directly to the movement, to the association of intrusive rocks with the movement, to the original condition of the rocks, or to the thermal conditions under which the movement was carried on, is at present an unsettled question. The intensity of the movement diminishes when traced through the Southern Uplands into the Lake District and again into North Wales; even here it is accompanied by thrusting and cleavage. The latter affects Silurian as well as Ordovician and Cambrian rocks, but it is not known to affect anything newer. Mr. Harker has shown that in Carnarvonshire the location of the cleavage can be connected with the presence of hard, old, masses of resistant rock; it is remarkable that the Longmynd has not produced like results in its neighbourhood. It may be argued that the pressures had here considerably diminished. A similar absence of cleavage is evident in the Nuneaton Cambrian rocks, despite the presence of the Charnian mass.

The Pennine movement has been restricted in its effects to the production of folds and faults without cleavage or overthrust; but the Armorican movement proper at its maximum intensity has been enough to produce the gneisses and schists of Britanny and of Devon and Cornwall. All later movements have resulted in nothing more serious than a certain amount of folding and faulting, crushing, thinning out, and occasional overthrust.

The connexion of vulcanicity with earth-movement has long been recognised, and is being more fully illuminated by the active petrographical research that is now going on. Each period of orogenic movement in Britain has been connected with one or more of the phases of extrusive or intrusive action, volcanoes, plutonic intrusion, or minor intrusion. So far as the composition of the rocks is concerned, as Mr. Harker has pointed out, the Pacific type dominates over the Atlantic type. The igneous action tends to occur on the margin of the great Atlantic continent, to break through the older rocks where the cover is thin or absent, and to be associated with regions in which contemporary or posthumous folding is asserting or about to assert itself. Thus the dominance of the Pacific type of rocks may possibly be connected with the general dominance through British geological history of geographical features of 'Pacific' rather than 'Atlantic' type. The exceptions will probably be explicable when we possess a

more complete knowledge of the detailed succession and nature of the movements of each period.

So far as time is concerned, extrusive igneous action has been associated mainly with the close of geosynclinal conditions, while intrusive, and particularly plutonic, activity has been connected with the formation of geanticlines and orogenic uplift. The variation which shows itself in the products of a single petrographical province seems to be, in the main, due to differentiation; and we owe to Mr. G. Barrow and Mr. A. Harker the valuable suggestion that one of the chief determining factors in the progress of differentiation is the action of varying pressures on a magma in a state of partial or of potential fluidity. This suggestion, though not yet fully worked out, promises to be a most fruitful one, and holds out hopes of establishing a closer relationship than has hitherto been possible between the structures of the earth-crust and the nature and distribution of igneous material in connexion with it.

Mr. Finlayson has recently attempted to work out the relation between the periods of earth-movement and the formation of ore-bodies. He finds that only a small proportion of our metalliferous veins date back to the Caledonian or earlier movements, but that the great period of vein-filling was associated with the post-Carboniferous movement, even in areas where the country rocks are of Ordovician or of Silurian age. Ores found in post-Carboniferous rocks have in most cases been deposited there by redistribution, concentration, and enrichment from earlier deposits. If he is right in his contention, he has given to the Later Palæozoic Era a further claim on our gratitude for its contributions to the mineral wealth of our country.

The connexion is probably only indirect between the several movements which have affected the British Isles and their present systems of drainage and consequent relief. While the Wealden dome is drained by a system of rivers that dates to the Alpine movement, and the Thames and Solent valleys are consequent on structures due to that movement, phenomena apparently similar in Wales, Lakeland, and the Pennine Chain cannot be similarly linked with older movements. The number of submergences and planations, the covering with sediment and the subsequent removal of it, have probably destroyed or buried lines of drainage due to earlier movements, and such relationships as still subsist are due to that adjustment of drainage to structure which must always work itself out eventually, on whatever lines it may make

its start. It is doubtful whether, in any case, we can go back farther than the great Chalk covering for the initiation of the earliest of our existent drainage-lines, and even drainage initiated in Tertiary times has in many cases suffered serious modifications during the latter part of that Era.

(10) Earth-Movement and Life.

There can be little doubt that a biological reflexion of the changes in physical geography of even a small area like our own country will be found in the progress of its life, if this is definitely looked for by palæontologists. Just as, locally at any rate, unfavourable circumstances have certainly retarded or shifted the direction of evolution, so the coincidence of a number of favourable features must exercise a stimulating influence upon it. But the case must necessarily be much complicated by the action of other factors in the physical environment, and the reactions of organisms upon each other.

As an example, we may take the point made by Starkie Gardner when he showed that one of the most potent factors in mammalian development must have been the coming into existence of grasses and herbage plants. These had a physical reaction upon the formation of soil and in modifying the course and extent of denudation, while biologically they gave a great impetus to the development of the Herbivora. But the extensive development of these plants coincided with, and was partly dependent upon, the production of wide and suitable plains on which there could be established savannahs replacing many of the forests and swamps. Following on this came a fresh impetus to the development of migratory habits associated with power of speed, which in its turn gave an impulse to the evolution of animals of gregarious habits on the one hand and of hunting habits on the other.

There are two essays which, even at this late date, are well worth considering in this connexion. One is the Presidential Address delivered to this Society by Huxley in 1870, in which he dealt with evolution in geological time and the relation of successive faunas to one another. The other is a paper by Searles V. Wood, Jun., published in 1862,[1] of the existence of which Huxley was unaware when writing the Address just mentioned.

In the latter the author endeavoured to supply a physical explanation in the first place of the exaggerated development of

---

[1] Phil. Mag. vol. xxiii, pp. 161–71, 269–82, 382–93.

reptiles during Mesozoic times, and in the second place of the rapid diminution of these forms and their replacement by mammals in the Tertiary Era. The first he attributed largely to the peculiar physical features which characterised the Mesozoic geography, the second to the remarkable changes in these features initiated by the Tertiary revolution. Although the exact conditions of physiography which were postulated by the author will hardly stand in the light of our present knowledge of these geographies, the essay is of extraordinary interest and importance in, thus early, directing attention to the bearing of physical changes on problems of the evolution of life.

The earth's surface is the theatre of two types of change:—Those which are external and comprise chiefly the influence of the sun upon the air, land, and water; and those which are internal and depend on earth-movement. The last may be attributable entirely to the activity of the interior, or possibly may be in part due to the influence of external bodies, such as the sun and moon, as well. To a large extent these two sets of influences must be independent. We can grasp the possibility of a world's population evolving under the influence of either of these suites of conditions acting in the absence of the other. But, if the two are acting together, the results will become of a much more highly complex character, because with two independently acting variables there must necessarily be periods of coincidence and of interference in the effects produced.

We should expect, in these circumstances, that epochs of relative acceleration and retardation of evolution would occur with a certain amount of apparent irregularity in period, complicating very considerably the otherwise steadfast advance in life.

Such striking differences as the outline, trend, contour-plan, and latitudinal extension of the New World in contrast with the Eurasian continent; or the remarkable difference between the Atlantic and Pacific Oceans in their coasts, depths, and structures, will illustrate my meaning. And we have to recognise that differences probably as marked as these have swept over the places now occupied by single continents and oceans in different stages of their history.

In the distribution of animals and plants at the present day there is found recorded many of the physical changes that the lands which they have inhabited have undergone. Is it too much to hope that we may one day recognise, stored up in the organisation of the creatures themselves, and in their ancestral history

a record of the physical factors which have been one of the impelling causes of their evolution?

In this branch of enquiry, however, the palæogeography of a single region, even when it embraces a whole country whose past geological conditions have been so varied and typical as our own, is inadequate to the strain of all-embracing generalisations; and the study of a whole continent, or, better, of the world itself as a whole, is essential before it will be possible to reach a true conception of the physical machinery which has been operating in evolution.

A corresponding world-wide outlook is also requisite when we wish to place in correct perspective the physical development of a limited area in association with the evolution of the physical features of the world as a whole. The more important stratigraphical works, like those of Sir Archibald Geikie in Britain, A. de Lapparent in France, and Chamberlin and Salisbury in America, have summarised for us the world-geology of the different Periods, from which we can obtain a general conception of the broad outlines of the geography of large areas of the world at different times. Salisbury and Willis for America, and de Lapparent for the whole world, have endeavoured to express in the form of maps the known geological facts that bear upon the geography of the different Periods. Even here, however, there is the serious handicap that two thirds of the earth's surface are covered by sea and inaccessible to observation.

But there is a vast amount of work still to be done in filling in the details of even the land portion of these maps, and each part so filled in will inevitably diminish the difficulties left in extending the lines in the areas into which our observations do not or cannot extend. It is only by work of this description, by obtaining a fuller and deeper knowledge of the whole of the events recorded in our strata throughout the world, that we shall ever approach the solution of the larger and more fascinating problems of Geology.

(11) Conclusion.

In conclusion, we may sum up some of the main points which have been touched upon. The History of the Earth, so far as the Geologist is capable of following it through the geological systems and formations, is a history of successive geographies, and of the relations of those geographies to the living beings which successively characterised them. In the reading and

restoration of those geographies there is but one unfailing guide, unceasing comparison, at every stage, of the ascertainable geological phenomena of the past with the known geographical phenomena of the present. But, in following that guide, every step must be made with the greatest caution and circumspection. It is not sufficient to recognise alone the fact that the succession of geological systems and formations is representative, on the whole, of geological time; but we must recognise the fact that each individual formation must be studied as a lithological unit, its local place and limits in time accurately fixed, and its time-equivalent elsewhere determined. In this task we meet at every stage on the one hand with unexpected difficulties, and on the other with unexpected interpretative geographical parallels. This gives to our work the interest of novelty and the charm of unceasing discovery, and to each one of us may come in turn the personal satisfaction of having contributed some new factor or some new generalisation to the History of the Earth.

February 22nd, 1911.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President,
in the Chair.

Augustus Hamilton, Director of the Dominion Museum, Wellington (New Zealand); and Thomas Herdman, B.Sc., The Grove, Alston (Cumberland), were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'The Geology of the Districts of Worcester, Robertson, and Ashton (Cape Colony).' By R. H. Rastall, M.A., F.G.S.

Baron Ferencz Nopcsa, Jr., then gave some account of the Geology of Northern Albania. He said that he had examined the greater part of the Province of Skutari in Western Turkey, and recognized three distinct structural units: namely, the North Albanian platform, the folded Tsukali, and the eruptive region of Merdita. In the first region Mesozoic limestones of all periods predominate; in the second region Mesozoic radiolarian chert is found; while in the third region Mesozoic clastic rocks, volcanic tuffs, and eruptive masses are abundant. The first and third units are not folded, but are, at least in part, overthrusts from the north and south respectively above the second (intermediate) unit, which is strongly folded. In Northern Albania Upper Carboniferous and Permian rocks are also distinguishable, and there is an Eocene Flysch.

The following specimens and lantern-slides were exhibited:—

Rock-specimens from the Worcester and Ashton districts of Cape Colony, exhibited by R. H. Rastall, M.A., F.G.S., in illustration of his paper.

Rock-specimens and fossils from Northern Albania, and lantern-slides, exhibited in illustration of Baron F. Nopcsa's remarks.

'Head of a man' in flint, from a gravel-pit at Beaconsfield (Buckinghamshire), exhibited by J. Allen Howe, B.Sc., F.G.S.

March 8th, 1911.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President,
in the Chair.

James Ford, The Woodlands, Mold (North Wales); and Thomas Harris Burton, Farnsfield (Nottinghamshire), were elected Fellows of the Society.

The List of Donations to the Library was read.

The President announced that the Council had awarded the Proceeds of the Daniel Pidgeon Fund for 1911 to Tressilian Charles Nicholas, B.A., Trinity College, Cambridge, who proposes to investigate the relations of the older rocks in the Lleyn Peninsula (Carnarvonshire).

The following communications were read :—

1. 'Contributions to the Geology of Cyrenaica.' By Prof. J. W. Gregory and others.

(i) The Geology of Cyrenaica. By John Walter Gregory, D.Sc., F.R.S., F.G.S., Professor of Geology in the University of Glasgow.

(ii) Notes on the Kainozoic Mollusca of Cyrenaica. By Richard Bullen Newton, F.G.S.

(iii) Foraminifera, Ostracoda, and Parasitic Fungi from the Kainozoic Limestones of Cyrenaica. By Frederick Chapman, A.L.S., F.R.M.S.

(iv) The Fossil Echinoidea of Cyrenaica. By John Walter Gregory, D.Sc., F.R.S., F.G.S.

(v) The Foraminiferal Limestones of Cyrenaica. By David Paterson MacDonald, M.A., B.Sc.

2. 'On the Teeth of the Genus *Ptychodus*, and their Distribution in the English Chalk.' By George Edward Dibley, F.G.S.

The following specimens, lantern-slides, and maps were exhibited :—

Rock-specimens and fossils, microscope-sections and lantern-slides, exhibited by Prof. J. W. Gregory, D.Sc., F.R.S., F.G.S., in illustration of the paper on Cyrenaica.

Mollusca and other fossils from that country, exhibited by R. B. Newton, F.G.S., in illustration of the same paper.

A series of teeth of *Ptychodus* from Kent and Surrey, exhibited by G. E. Dibley, F.G.S., in illustration of his paper.

Specimen of *Ptychodus decurrens* Ag., from the Chalk Marl of Glynde, north-east of Lewes, exhibited by Dr. A. Smith Woodward, F.R.S., F.L.S., Sec.G.S.

Geological Survey of Scotland: 6-inch Map of Lanarkshire, Sheet 7, N.W., S.E., & S.W. (Solid & Drift), 1910, presented by the Director of H.M. Geological Survey.

March 22nd, 1911.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President,
in the Chair.

Ernest Parsons, B.Sc., 13 Colville Terrace, Beeston Hill, Leeds, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'On some Mammalian Teeth from the Wealden of Hastings.' By Arthur Smith Woodward, LL.D., F.R.S., F.L.S., Sec.G.S.

2. 'Some Observations on the Eastern Desert of Egypt; with Considerations bearing on the Origin of the British Trias.' By Arthur Wade, B.Sc., F.G.S.

3. 'Faunal Horizons in the Bristol Coalfield.' By Herbert Bolton, F.R.S.E., F.G.S.

The following lantern-slides and specimens were exhibited :—

Lantern-slides exhibited by Dr. A. Smith Woodward, F.R.S., F.L.S., Sec.G.S., in illustration of his paper. Also specimens exhibited by C. Dawson, F.S.A., F.G.S., in illustration of the same.

Rock-specimens, minerals, and fossils from the Eastern Desert of Egypt, with microscope-sections and lantern-slides, exhibited by A. Wade, B.Sc., F.G.S., in illustration of his paper.

Fossils from various faunal horizons in the Bristol Coalfield, exhibited by H. Bolton, F.R.S.E., F.G.S., in illustration of his paper.

April 5th, 1911.

Dr. C. W. Andrews, B.A., F.R.S., Vice-President,
in the Chair.

Frank Elgee, 23 Kensington Road, Middlesbrough; and Morgan David Williams, 23 Morlais Street, Cardiff, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read :—

1. 'Trilobites from the *Paradoxides* Beds of Comley (Shropshire).' By Edgar Sterling Cobbold, F.G.S. (with Notes on some of the Associated Brachiopoda, by Charles Alfred Matley, D.Sc., F.G.S.).

2. 'The Stratigraphy and Tectonics of the Permian of Durham (Northern Area).' By David Woolacott, D.Sc., F.G.S.

The following specimens, lantern-slides, and maps were exhibited:—

A series of trilobites and brachiopoda from the Comley *Paradoxides* Beds, and lantern-slides, exhibited by E. S. Cobbold, F.G.S., in illustration of his paper.

Specimens of *Paradoxides groomii* Lapw., exhibited by Prof. Charles Lapworth, LL.D., M.Sc., F.R.S., F.G.S., in illustration of Mr. Cobbold's paper.

Rock-specimens and fossils from the Permian of North Durham, with two geological models and several lantern-slides, exhibited by Dr. David Woolacott, F.G.S., in illustration of his paper.

Geological Map of the Pre-Quaternary Systems of Sweden, 1:1,500,000, by A. E. Törnebohm & others, 2nd ed. 1910; Das Spätglaciale Süd-Schweden: Uebersichtskarte mit Osen, Endmoränen & Schrammen, 1:500,000, by Gerard de Geer, 1910; and Map of Land-Forms in the neighbourhood of the great Swedish Lakes, 1 : 500,000, by Sten de Geer, 1910, presented by the Director of the Geological Survey of Sweden.

April 26th, 1911.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The President made the following announcement:—

'By the decease of Prof. Thomas Rupert Jones, F.R.S., in his 92nd year, the Geological Society has lost one of its oldest and most valued members, who was formerly (1850-1862) Assistant Secretary of the Society, and Editor of the Quarterly Journal. During his long life Prof. Rupert Jones was an ardent geologist and palæontologist, and has left behind him in the Palæontographical Society's Memoirs, in the Quarterly Journal of the Geological Society, in the "Geological Magazine," and in the "Annals & Magazine of Natural History" no mean record of his abilities and strenuous labours. Nor was his work confined to original papers, but as Editor of the Quarterly Journal of the Geological Society, the "Geological Magazine," the "Reliquiæ Aquitanicæ," Dixon's "Geology of Sussex," the "Arctic Manual," and other works, he showed a high-class capacity in literature.

'Never in receipt of more than a very moderate income, derived from a small pension upon his retirement from the post of Professor of Geology in the Royal Military College, Sandhurst, he was unable to make any suitable provision for his death (when his pension ceased), and has left a widow with two daughters and an invalid son, almost wholly unprovided for.

'It is proposed to form a Committee of Geologists to consider the means of providing some memorial in aid of the widow and daughters of the late Professor. Any Fellows present willing to assist in this object are requested to communicate with the Assistant Secretary.'

The following communication was read :—

'The Llandovery and Associated Rocks of North-Eastern Montgomeryshire.' By Arthur Wade, B.Sc., F.G.S.

Dr. J. D. FALCONER, M.A., F.G.S., then gave an account of the Geology of Northern Nigeria, illustrating his remarks by means of lantern-slides. He pointed out that the Protectorate of Northern Nigeria covers an area of about 255,000 square miles, over half of which crystalline rocks are exposed at the surface. A series of hard banded gneisses of an Archæan type is intermingled with a series of quartzites, phyllites, schists, and gneisses of sedimentary origin, in such a way as to suggest that the two series, while originally unconformable, have been at a later period affected by a common folding and foliation along axes which are predominantly meridional in direction. The two series have also been pierced by numerous igneous intrusions of a granitic type, which are subdivided into (1) an older, wholly or partly foliated group, and (2) a younger non-foliated group, characterized by the predominance of soda-bearing types.

Folded and faulted rocks of Cretaceous age are found in the valleys of the Benue and the Gongola. They consist of a lower series of sandstones and grits, in places salt-bearing, and an upper series of limestones and shales with numerous fossils of Turonian age. These Cretaceous rocks are overlain unconformably by a horizontal series of sandstones, grits, conglomerates, and ironstones, which in Sokoto province contains intercalations of Middle Eocene limestone. Considerable volcanic activity occurred during Tertiary times, and gave rise to extensive fields of basaltic lava in Bauchi and Bornu, as also to numerous puys of trachyte, phonolite, olivine-basalt, and nepheline-basalt throughout Southern Bauchi, Muri, and Yola. Repeated minor oscillations of the crust occurred during the latter part of the Tertiary Era, and culminated in the elevation of the Bauchi plateau, the depression of the Chad area, and the establishment of the present river-system.

In addition to the lantern-slides above mentioned, the following exhibits were shown :—

Rock-specimens, fossils, microscope-sections, and lantern-slides, exhibited by Arthur Wade, B.Sc., F.G.S., in illustration of his paper.

Drawings and models, exhibited by Oswald H. Evans, F.G.S., to illustrate the gliding flight of the *Archæopteryx*.

Worked flints obtained from gravels overlying Tertiary limestones, near Campeche (Mexico), exhibited by Leonard V. Dalton, B.Sc., F.G.S.

May 10th, 1911.

Prof. W. W. Watts, Sc.D., M.Sc., F.R.S., President, in the Chair.

Herbert Stanley Bion, B.Sc., Assistant Superintendent, Geological Survey of India, Calcutta; J. S. Freeman, Buckfastleigh, Church End, Finchley, N.; Harman Milton, 23 Sussex Place, Regent's Park, N.W.; Rowland Edgar Nicholas, F.L.S., Bitterne Park (Hampshire); Harold Hyde Ridsdale, Kelfield Lodge, Streetly, near Birmingham; and Edwin Taylor, B.Sc., Lecturer in Physical Science in the Consett Technical Institute, Lennel House, Blackhill, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Lower Carboniferous Succession in the North-West of England.' By Prof. Edmund Johnston Garwood, M.A., Sec.G.S.

2. 'The Faunal and Lithological Sequence in the Carboniferous Limestone (Avonian) of Burrington Combe, Somerset.' By Prof. Sidney Hugh Reynolds, M.A., F.G.S., and Arthur Vaughan, M.A., D.Sc., F.G.S.

Mr. S. Hazzledine Warren exhibited a piece of worked wood, possibly the point of a palæolithic spear. It measured $15\frac{1}{4}$ inches in length and $1\frac{1}{2}$ inches in thickness; one end had been carefully fashioned to an acute point, the other end was broken. Mr. Warren said that he had quite recently dug it out of an undisturbed part of the freshwater deposit of Clacton-on-Sea. This deposit yields remains of *Elephas antiquus*, *Rhinoceros*, and other Pleistocene mammalia in abundance, as also palæolithic flint-implements, some of which were now exhibited. The contemporaneity of the pointed shaft—with the Pleistocene deposit in which it was found—was confirmed by the fact that it agreed in condition with the wood that is extremely plentiful in the same bed. It also had calcareous encrustations upon its surface, such as were seen on other remains from this deposit.

In addition to the specimen above described, the following exhibits were shown:—

Fossils, rock-specimens, microscope-sections, and lantern-slides, exhibited by Prof. E. J. Garwood, M.A., Sec.G.S., in illustration of his paper.

Fossils, rock-specimens, microscope-sections, and lantern-slides, exhibited by Prof. S. H. Reynolds, M.A., F.G.S., and Dr. A. Vaughan, M.A., F.G.S., in illustration of their paper.

May 24th, 1911.

Prof. W. W. WATTS, Sc.D., M.Sc., F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The Names of certain Fellows of the Society were read out for the first time, in conformity with the Bye-Laws, Section VI, Art. 5, in consequence of the Non-Payment of the Arrears of their Contributions.

The following communication was read :—

'On the Geology of Antigua and other West Indian Islands, with Reference to the Physical History of the Caribbean Region.' By R. J. Lechmere Guppy. (Communicated by Prof. E. J. Garwood, M.A., Sec.G.S.)

Prof. W. J. POPE, M.A., F.R.S., gave a demonstration of new processes of colour-photography, as applied to Mineralogy and Geology, illustrated by a series of extremely beautiful lantern-slides.

The demonstration was followed by a Discussion, in which the PRESIDENT, Dr. J. J. H. TEALL, Prof. E. J. GARWOOD, Prof. J. W. JUDD, Dr. J. W. EVANS, and Mr. G. W. YOUNG took part, and to which Prof. POPE replied.

The following exhibits were shown :—

Fossiliferous Millstone Grit from the Drift of Hertford, exhibited by A. H. Williams, F.G.S.

'Implement' from (?) Carisbrooke (Isle of Wight), exhibited on behalf of Mr. F. Morey, by A. W. Oke, B.A., F.L.S., F.G.S.

June 14th, 1911.

Prof. W. W. WATTS, Sc.D., M.Sc., F.R.S., President,
in the Chair.

Reginald Cooksey Burton, B.Sc., 84 Princes Street, Bishop Auckland, and Armstrong College, Newcastle-on-Tyne; George Hogben, M.A., Inspector-General of Schools in New Zealand, Wellington (N.Z.); Tressilian Charles Nicholas, B.A., Trinity College, Cambridge; Ernest Sheppard Pinfold, Undercliff Cottage, Bradford; Ira Cyril Frank Statham, 71 Hednesford Road, Heath Hayes,

Cannock (Staffordshire); and Henry Crunden Sargent, Ambergate (Derbyshire), were elected Fellows of the Society.

The PRESIDENT announced, with a regret which he was assured all the Fellows would share, the unexpected decease at Karlsbad of Prof. VICTOR KARL UHLIG, University of Vienna, who was to have been balloted for as Foreign Correspondent.

The List of Donations to the Library was read.

The Names of certain Fellows of the Society were read out for the second time, in conformity with the Bye-Laws, Section VI, Art. 5, in consequence of the Non-Payment of the Arrears of their Contributions.

The following communications were read:—

1. 'On a Monchiquite Intrusion in the Old Red Sandstone of Monmouthshire.' By Prof. William S. Boulton, B.Sc., Assoc.R.C.S., F.G.S.

2. 'Notes on the Culm of South Devon: Part I—Exeter District.' By Frederick George Collins, F.G.S.; with a Report on the Plant-Remains by E. A. Newell Arber, M.A., F.G.S., and Notes on the Cephalopoda, by George C. Crick, Assoc.R.S.M., F.G.S.

The following specimens, maps, etc. were exhibited:—

Hand-specimens, microscope-sections, photographs, and lantern-slides, exhibited by Prof. W. S. Boulton, B.Sc., Assoc.R.C.S., F.G.S., in illustration of his paper.

Fossils, rock-specimens, and lantern-slides, exhibited by F. G. Collins, F.G.S., in illustration of his paper.

Fossils exhibited by G. C. Crick, Assoc.R.S.M., F.G.S. (by permission of Dr. Wheelton Hind, F.G.S.), for comparison with the specimens exhibited by Mr. F. G. Collins.

A specimen of cleaved volcanic ash, showing some peculiar effects of cleavage, one side of the specimen being three-quarters of an inch thick, the opposite side thinning to a cutting-edge, and numerous crystals of pyrite being elongated to three or four times their width. From Homster Slate-Quarries (Cumberland), exhibited by John Postlethwaite, F.G.S.

Twenty-four sheets of the 6-inch Geological Survey Map (Drift) of England and Wales, presented by the Director of H.M. Geological Survey.

Royal Geological Institute of Hungary: Geological Map on the scale of 1 : 75,000—Sheet Zone 22, Kol. xxix, Szaszsebes, 1909. Presented by the Director of that Institute.

A SPECIAL GENERAL MEETING was held before the Ordinary Meeting at 7.30 P.M., in order to consider the following resolutions:—

> (1) That the contents of the Geological Society's Museum, with the exception of those marked A, which are conspicuously displayed in the Society's Apartments, be offered to the Trustees of the British Museum (Natural History), and to the Director of the Museum of Practical Geology (Jermyn Street).
>
> (2) That the Council be instructed to offer the British specimens to the Director of the Museum of Practical Geology, and the Foreign and Colonial specimens to the Trustees of the British Museum (Natural History).
>
> (3) That, in the event of the acceptance of both gifts, the Council be empowered to transfer the collections to those two Institutions, in accordance with the conditions which have been provisionally arranged.
>
> (4) That the Treasurer be authorized to expend a sum not exceeding £250, in adapting the space thus vacated by the Collections for the purposes of the extension of the Library.

Resolution (1) was passed by 29 Ayes to 1 No, and Resolutions (2), (3), and (4) were passed *nemine contradicente.*

It was stated that, in accordance with Resolution 4 passed at the Special General Meeting on January 25th, 1911, and confirmed at the Annual General Meeting on February 17th, the Council had approached the Trustees of the British Museum (Natural History) and the Director of the Museum of Practical Geology, and understood that they were willing respectively to accept the parts of the Collections mentioned in the foregoing resolutions, under the conditions set out as follows:—

> All type-specimens and figured specimens, and all material of exceptional value and importance in illustrating the advance of Geology, as registered in publications and especially in publications of the Society, are to be retained by the British Museum and the Museum of Practical Geology respectively.
>
> But, when the Officers of these Museums have had ample time to work through the Collections, there will probably remain a considerable amount of material which it would not be necessary for the Museums to retain permanently. The Officers of these Museums will draw up a report specifying any proposed disposal of such material, and present it to the Society for its approval. The Council will furnish the two Museums with copies of the letters which have been received, containing requests for gifts of duplicate and other material. While desiring that such requests, and others that might be subsequently made, should receive consideration, the Society will doubtless have no wish to restrict the action of the Officers of the two Museums in this matter, but will repose entire confidence in any action which they may see fit to take.

The list of specimens marked A, to which reference was made in Resolution (1), is here given in full:—

Specimens illustrating the Alluvial Gold-Deposits of New South Wales. Presented by Sir Daniel Cooper.

Canis palustris, from the Upper Miocene Freshwater Limestone of Œningen (Switzerland). Presented by Sir Roderick I. Murchison.

Ichthyosaurus, from the Lower Lias of Barrow-on-Soar (Leicestershire).
Skull of *Ichthyosaurus platyodon* Conybeare, from the Lower Lias of Lyme Regis. Presented by several Fellows of the Society—unnamed.
Ichthyosaurus intermedius Conybeare, from the Lias of Lyme Regis. Presented by Sir Henry T. De la Beche.
Pentacrinites briareus, from the Lias of Lyme Regis. Presented by Sir Henry T. De la Beche.
Tree-Section.
Portion of Trunk of an Oak, from the Submarine Forest near St. Leonards-on-Sea. Presented by Sir Woodbine Parish.
Part of the Silicified Trunk of a Coniferous Tree (*Cedroxylon*), from the Purbeck Beds, Isle of Wight. Presented by John Fisher.
Ammonite (*Haploceras lewesiense* Mantell, sp.) from the Chalk of Tusburgh (Norfolk). Presented by John Wright.
Two ammonites (over doorways).
Paramoudra, Upper Chalk, believed to be from near Norwich (Norfolk).
Paramoudra, Upper Chalk, Norfolk. Presented by the Rev. J. Gunn.
Two specimens of *Cervus megaceros* from a peat-bog, Ireland.
Rhinoceros tichorhinus, King's Newnham, near Church Lawford (Warwickshire). Presented by Dean Buckland.
Two specimens of *Bison priscus*, one from Walton (Essex), presented by J. T. Wetherell.
Two skulls of *Bos longifrons* (over doorways).
Tusk of Mammoth (*Elephas primigenius*), from Siberia.
Tusk of Elephant, said to be from the Forest Bed (Norfolk).
Slab of Wenlock Limestone with *Periechocrinus moniliformis*, *Favosites*, and other fossils, from Dudley (Worcestershire). Presented by the Earl of Dudley.
Isle of Wight Greensand Section.
Meteoric Iron from Zacatecas (Mexico). Presented by Sir Woodbine Parish.
Meteoric Iron from Atacama (Peru). Presented by Capt. Colquhoun & Joseph Burkart.
Fulgurites from Drigg (Cumberland).
Les Eyzies (slab with worked flints and bones).
Model of Granite Veins (intrusive in schist), Galloway (Scotland).
Model of Arthur's Seat and the King's Park at Edinburgh, showing geological structure, by J. Robison Wright.
Model of Mount Etna.
Model of Mount Vesuvius.
Columns of Basalt from the Giants' Causeway (Antrim). Presented by John Wiggins.
Glaciated boulder from Scotland. Presented by Robert Chambers.
Quartz (in officers' room).

Luc